In compliance with the
Canadian Privacy Legislation
some supporting forms
may have been removed from
this dissertation.

While these forms may be included
in the document page count,
their removal does not represent
any loss of content from the dissertation.

University of Alberta

Tannin Free Faba Bean (*Vicia faba* L.) Production in North Central Alberta

by

Sheryl Marie Strydhorst

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

Master of Science

in

Plant Science

Department of Agricultural, Food and Nutritional Science

Edmonton, Alberta

Fall 2003

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisisitons et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-612-87891-0
Our file Notre référence
ISBN: 0-612-87891-0

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou aturement reproduits sans son autorisation.

Canada

University of Alberta

Library Release Form

Name of Author: **Sheryl Marie Strydhorst**

Title of Thesis: **Tannin Free Faba Bean (*Vicia faba* L.) Production in North Central Alberta**

Degree: **Master of Science**

Year this Degree Granted: **2003**

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis and lend or sell such copies for private, scholarly, or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided, neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's written permission.

S. Strydhorst

Sheryl Strydhorst

Box 270

Neerlandia, AB

T0G 1R0

Date: Aug 15/03

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for the acceptance, a thesis entitled **Tannin Free Faba Bean (*Vicia faba* L.) Production in North Central Alberta** submitted by Sheryl Marie Strydhorst in partial fulfillment of the requirements for the degree of Master of Science in Plant Science.

Dr. J. R. King

Dr. D. Spaner

Dr. L. Fuller

Date July 30, 2003

Abstract

The effects of altering seeding date (early, mid, late), seeding rate (32, 43, 65 plants m^{-2}), and cultivar (Cresta and Snowbird, tannin free; Earlibird and Blitz, tannin containing), on faba bean (*Vicia faba* L.) production were investigated at two locations in north central Alberta in 2001 and 2002. Optimal yields were achieved at the mid seeding date. Optimum seeding rate varied with environmental conditions. Seed tannin content did not influence yield, yield components, seed protein content, or maturity. Under cold and wet soil conditions plant populations of the tannin free cultivars were reduced 15-30% which affected yield in some instances. Chemical desiccants (diquat, glyphosate) were applied at the 60-70% or 90-95% black pod stage. Desiccation advanced maturity and improved harvestability, without reducing yield or seed weight. Diquat applied at the 60-70% black pod stage was the most effective treatment. Tannin free faba beans can be successfully grown in north central Alberta.

Dedication

To Shane, Mom, Dad, and Sheila

ACKNOWLEDGEMENTS

I would like to thank Dr. Jane King for all of her guidance, advice, and support throughout the time it has taken me to complete this project. I would also like to thank Dr. Dean Spaner for sharing his statistical knowledge and thoughtful suggestions with me on this project. To Dr. Les Fuller, I appreciate you taking time out of your busy schedule to participate in this project. I greatly appreciate all of the constructive suggestions and investment of time my supervisor and committee has made in reviewing this thesis.

Appreciation is expressed to the Alberta Pulse Growers – Zone 3 for funding of the project and to NSERC for providing myself with finding. I would like to express a special thank you to Ken Lopetinsky and Bob Park for their technical advice and first hand knowledge with this crop and the project.

This project would not have been possible without the technical support of Shirley Brezden, Len Steel, Maureen Essensa, Tanis Wagner, Raelene Ostrum, Shannon Tuininga, and Shawn Mudryk. A special thanks to my husband Shane, my Mom, and sister Sheila for long hours of counting yield components with me.

Most importantly, I want to thank Shane and my family for their continual love and support throughout this project.

TABLE OF CONTENTS

Chapter 1 Faba bean (Vicia faba L.)Introduction and Objectives

1.1 Distribution and Origin 1

1.2 Taxonomy 2

1.3 Cultivars 4

1.4 Morphology 5

1.5 Worldwide Uses 6

1.6 Agronomic Practices 7

1.6.1 Nitrogen Fixation Benefits 10

1.6.2 Seeding Date 11

1.6.3 Seeding Rate 12

1.6.4 Row Spacing 14

1.6.5 Yield Components 15

1.6.6 Disease Problems 17

1.6.6.1 Chocolate Spot 17

1.6.6.2 Ascochyta Blight 19

1.6.6.3 Rust 19

1.6.6.4 Sclerotinia Stem Rot 20

1.6.6.5 Fusarium Root and Foot Rot 21

1.6.7 Insect Pest Problems 22

1.6.7.1 Black Bean Aphid 22

1.6.7.2 Stem Nematode 23

1.6.7.3 Lygus Bugs 23

1.6.8 Weed Problems 24

1.6.8.1 Cultural Control Methods 24

1.6.8.2 Chemical Control Methods 24

1.6.9 Harvest Management Techniques 25

1.7 Tannin-free Faba Bean 27

1.7.1 Agronomic Challenges 29

1.7.2 Fungistatic Properties of Tannins 30

1.7.3 Interaction of Early Planting and Seedling Disease 31

1.8 Research Objectives 33

1.9 Literature Cited 33

Chapter 2 Effects of Cultivar, Seeding Date, and Seeding Rates on Faba Bean Yield and Quality

2.1 Introduction 43

2.2 Materials and Methods 46

2.2.1 Experimental Design 46

2.2.2 Soil Sampling 48

2.2.3 Environmental Data 49
2.2.4 Weed Control and Plot Maintenance 50
2.2.5 Plant Populations 50
2.2.6 Days to 10% Flower 51
2.2.7 Chocolate Spot Assessments 51
2.2.8 Leaf Drop Assessment 51
2.2.9 Plant Height Measurements 52
2.2.10 Lodging Assessment 52
2.2.11 Physiological Stage at Harvest 52
2.2.12 Seed Yield 53
2.2.13 Protein Analysis 53
2.2.14 Statistical Analysis 53

2.3 Results 54
2.3.1 Environmental Data 54
2.3.2 Soil Nitrogen 55
2.3.3 Year and Location 55
2.3.4 Legal 2001 57
2.3.5 Neerlandia 2001 60
2.3.6 Legal 2002 63
2.3.7 Neerlandia 2002 67

2.4 Discussion 70
2.4.1 Yield and Rate of Yield Gain 70
2.4.2 Plant populations 74
2.4.3 Days to 10% Flower 76
2.4.4 Chocolate Spot Infection 77
2.4.5 Leaf Drop Assessment 79
2.4.6 Plant height 80
2.4.7 Lodging 81
2.4.8 Physiological Stage at Harvest 82
2.4.9 Crude Protein Content 83
2.4.10 Soil Nutrient Changes 84
2.4.11 Cultivar Performance 84

2.5 Conclusions 87

2.6 Literature Cited 116

Chapter 3 Effects of Cultivar, Seeding Date, and Seeding Rates on Faba Bean Yield Components

3.1 Introduction 121

3.2 Materials and Methods 123
3.2.1 Experimental Design 123
3.2.2 Soil Sampling 123
3.2.3 Environmental Data 123
3.2.4 Weed Control and Plot Maintenance 123
3.2.5 Plant Populations 123
3.2.6 Yield Component Assessment 123
3.2.7 Seed Yield and Seed Weight 123
3.2.8 Statistical Analysis 124

3.3 Results **124**
3.3.1 Environmental Data 124
3.3.2 Year and Location 124
3.3.3 Legal 2001 126
3.3.4 Neerlandia 2001 127
3.3.5 Legal 2002 130
3.3.6 Neerlandia 2002 132
3.3.7 Correlations 135

3.4 Discussion **136**
3.4.1 Response to Seeding Date 136
3.4.2 Response to Seeding Rate and Cultivar 137
3.4.2.1 Yield 137
3.4.2.2 Plant populations 138
3.4.2.3 Tillers 139
3.4.2.4 Total Nodes and Flowering Nodes 141
3.4.2.5 Pods per Node 142
3.4.2.6 Pods per Plant 142
3.4.2.7 Seeds per Pod 143
3.4.2.8 Seed Weight 143
3.4.3 Correlations between yield components 144

3.5 Conclusions **145**

3.6 Literature Cited **166**

Chapter 4 Effects of Harvest Management Tools on Faba Bean Yield

4.1 Introduction **170**

4.2 Materials and Methods **172**
4.2.1 Experimental Design 172
4.2.2 Soil Sampling 174
4.2.3 Environmental Data 174
4.2.4 Weed Control and Plot Maintenance 174
4.2.5 Plant Populations 175
4.2.6 Chocolate Spot Assessments 175
4.2.7 Leaf Drop Assessment 175
4.2.8 Plant Height Measurements 175
4.2.9 Late Season Stem Disease 176
4.2.10 Physiological Stage at Harvest 176
4.2.11 Seed Yield and Seed Weight 176
4.2.12 Statistical Analysis 177

4.3 Results and Discussion **177**
4.3.1 Environmental Data 177
4.3.2 Plant Populations 177
4.3.3 Chocolate Spot and Leaf Drop 177
4.3.4 Plant Height Measurements 179
4.3.5 Late Season Stem Disease 179
4.3.6 Physiological Stage at Harvest 179
4.3.7 Seed Yield 182
4.3.8 Seed Weight and Seed Shatter 184

4.4 Conclusions 185
4.5 Literature Cited 197

Chapter 5 Tannin-free Faba Bean Production in North Central Alberta 199
5.1 General Discussion and Conclusions 199
5.2 Literature Cited 204

Appendix I 205
Appendix II 213
Appendix III 216

LIST OF TABLES

CHAPTER TWO

Table 2.1: Schedule of events for the experiment at Legal and Neerlandia in 2001 and 2002. 89

Table 2.2: Significance of Year, Location, and Year x Location for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), percent of plot that lodged (LDG), physiological stage at harvest 2001; % black stems (PHYS 2001), physiological stage at harvest 2002; % black pods (PHYS 2002), and percent crude protein (PROT). 89

Table 2.3: Significance of seeding date, seeding rate, and cultivar for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), percent of plot that lodged (LDG), physiological stage at harvest; % black stems (PHYS), and percent crude protein (PROT) in 2001 at Legal and Neerlandia. 90

Table 2.4: Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black stems (PHYS) at Legal in 2001. 91

Table 2.5: Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), percent of plot that lodged (LDG), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black stems (PHYS), and percent crude protein (PROT) at Neerlandia in 2001. 92

Table 2.6: Significance of seeding date, seeding rate, and cultivar for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black pods (PHYS), and percent crude protein (PROT) in 2002 at Legal and Neerlandia. 93

Table 2.7: Seeding date, seeding rate, and cultivar effects on YLD (yield; t ha^{-1}), GAIN (yield gain per day; kg ha^{-1} day^{-1}), PLNT (plant population; plants m^{-2}), HGT (height; cm), FLR (days to 10% flower; from the day of seeding), CHC

(chocolate spot infection; 1-9), and PHYS (physiological stage at harvest; % black pods) at Legal in 2002..... 94

Table 2.8: Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black pods (PHYS), and percent crude protein (PROT) at Neerlandia in 2002. 95

CHAPTER THREE

Table 3.1: Schedule of events for the experiment at Legal and Neerlandia in 2001 and 2002. 148

Table 3.2: Significance of Year, Location, and Year x Location for YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$). 148

Table 3.3: Significance of seeding date, seeding rate, and cultivar for YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Legal and Neerlandia in 2001. 149

Table 3.4: Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Legal in 2001. 150

Table 3.5: Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Neerlandia in 2001. 151

Table 3.6: Significance of YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Legal and Neerlandia in 2002..... 152

Table 3.7: Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Legal in 2002. 153

Table 3.8: Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; g 1000 $seeds^{-1}$) at Neerlandia in 2002. 154

Table 3.9: Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; g 1000 $seeds^{-1}$), and YLD (yield; t ha^{-1}), in all site years..... 155

Table 3.10: Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; g 1000 $seeds^{-1}$), and YLD (yield; t ha^{-1}), in all site years for the cultivar Earlibird. 155

Table 3.11: Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; g 1000 $seeds^{-1}$), and YLD (yield; t ha^{-1}), in all site years for the cultivar Snowbird. 156

CHAPTER FOUR

Table 4.1: Schedule of events for the desiccation experiment at Legal and Neerlandia in 2001 and 2002. 187

Table 4.2: Desiccation application dates at Neerlandia and Legal in 2001 and 2002. 187

Table 4.3: Significance of Year, Location, and Year x Location for chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; g 1000 $seeds^{-1}$). 188

Table 4.4: Significance of Chemical desiccation treatment, Desiccation Application Date, and Cultivar for chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; g 1000 $seeds^{-1}$). 189

Table 4.5: Chemical desiccation treatment, Desiccation Application Date, and Cultivar effects on chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; g 1000 $seeds^{-1}$). 190

APPENDIX I

Table I-1: Seeding rates (kg ha^{-1}) of cultivars seeded in 2001 and 2002 206

Table I-2: Germination, vigor, emergence testing and EC (dSm^{-1}) of faba bean cultivars seeded in 2001 and 2002 206

Table I-3: Soil Analysis for Legal and Neerlandia 2001 (estimate of soil nutrients at beginning of the growing season) 207

Table I-4: Soil Analysis for Legal and Neerlandia 2002 207

Table I-5: Pre-Seeding and Post-Harvest Soil Analysis Comparison for Legal and Neerlandia 2002 208

Table I-6: Soil temperatures at time of seeding for Legal and Neerlandia in 2001 and 2002 208

Table I-7: Summary of monthly precipitation averages (mm) for Legal and Neerlandia for May to September in 2001 and 2002. 209

Table I-8: Mean Monthly Temperatures and Growing Degree Days in the AAFRD North Western Agriculture Region for 2001, 2002 and 30 Year Average (Alberta Agriculture Weather Summary, 2002). 209

Table I-9: Calculated growing degree days (GDD) for each seeding date from the time of seeding until the time of harvest in 2001 and 2002. 210

Table I-10: Time of plant population counts in 2001 and 2002 210

Table I-11: Nine-point chocolate spot assessment scale used in 2001 and 2002 210

Table I-12: Leaf Drop Rating Guidelines used in 2001 211

APPENDIX II

Table II-1: Analysis of Variance for yield of faba beans grown at Neerlandia and Legal in 2001 and 2002. 213

Table II-2: Analysis of Variance for yield of faba beans grown at Legal in 2001. 215

APPENDIX III

Table III-1: Analysis of Variance for yield of faba beans in desiccation experiment grown at Neerlandia and Legal in 2001 and 2002. 216

Table III-2: Analysis of Variance for yield of faba beans in desiccation experiment grown at Legal in 2001. 218

LIST OF FIGURES

CHAPTER ONE

Figure 1.1: Intraspecific classification of *Vicia faba* according to Muratova (1931). 3

CHAPTER TWO

Figure 2.1: Effect of seeding rate on plant population at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 96

Figure 2.2: Effect of seeding rate on physiological stage at harvest, at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 96

Figure 2.3: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.05). 97

Figure 2.4: Effect of seeding date on plant height for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 97

Figure 2.5: Effect of seeding date on days to 10% flower for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 98

Figure 2.6: Effect of seeding date on chocolate spot severity for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.05). 98

Figure 2.7: Effect of seeding date on physiological stage at harvest (percent black stems) for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 99

Figure 2.8: Effect of seeding rate on physiological stage at harvest (percent black stems) at three seeding dates grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate; p≤0.01). 99

Figure 2.9: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 100

Figure 2.10: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 100

Figure 2.11: Effect of seeding date on plant population for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 101

Figure 2.12: Effect of seeding date on plant height of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 101

Figure 2.13 Effect of seeding date on leaf drop of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 102

Figure 2.14: Effect of seeding date on lodging of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 102

Figure 2.15: Effect of seeding date on days to 10% flower of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 103

Figure 2.16: Effect of seeding date on days to chocolate spot severity of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 103

Figure 2.17: Effect of seeding date on crude protein content of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.05). 104

Figure 2.18: Effect of seeding date on physiological stage at harvest (% black stems) of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 104

Figure 2.19: Effect of seeding rate on yield at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.05). 105

Figure 2.20: Effect of seeding rate on days to 10% flower at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 105

Figure 2.21: Effect of seeding date on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 106

Figure 2.22: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 106

Figure 2.23: Effect of seeding date on days to 10% flower for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 107

Figure 2.24: Effect of seeding date on physiological stage at harvest for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 107

Figure 2.25: Effect of seeding rate on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; p≤0.01). 108

Figure 2.26: Effect of seeding rate on physiological stage at harvest (% black pods) for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; p≤0.01). 108

Figure 2.27: Effect of seeding rate on plant height at three seeding dates grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.05). 109

Figure 2.28: Effect of seeding rate on physiological stage at harvest (% black pods) at three seeding dates grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; p≤0.01). 109

Figure 2.29: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 110

Figure 2.30: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 110

Figure 2.31: Effect of seeding date on plant height of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 111

Figure 2.32: Effect of seeding date on days to 10% flower of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 111

Figure 2.33: Effect of seeding date on crude protein content of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 112

Figure 2.34: Effect of seeding date on physiological stage at harvest (% black pods) of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01). 112

CHAPTER THREE

Figure 3.1: Effect of seeding rate on plant population at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; P≤0.01). 157

Figure 3.2: Effect of seeding date on tillers per plant for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05). 157

Figure 3.3: Effect of seeding date on seed weight for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 158

Figure 3.4: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01)..... 158

Figure 3.5: Effect of seeding date on plant population for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 159

Figure 3.6: Effect of seeding date on seeds per pod of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 159

Figure 3.7: Effect of seeding date on seed weight of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 160

Figure 3.8: Effect of seeding rate on yield at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; P≤0.05). 160

Figure 3.9: Effect of seeding date on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 161

Figure 3.10: Effect of seeding date on tillers per plant for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05). 161

Figure 3.11: Effect of seeding date on seed weight for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 162

Figure 3.12: Effect of seeding rate on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; P≤0.01). 162

Figure 3.13: Effect of seeding rate on tillers per plant for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; P≤0.05). 163

Figure 3.14: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 163

Figure 3.15: Effect of seeding date on tiller per plant for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 164

Figure 3.16: Effect of seeding date on pods per node of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05). 164

Figure 3.17: Effect of seeding date on pods per plant of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 165

Figure 3.18: Effect of seeding date on seeds per pod of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 165

Figure 3.19: Effect of seeding date on seed weight of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01). 166

CHAPTER FOUR

Figure 4.1: Effect of chemical desiccant treatment on physiological stage at harvest for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Chemical desiccant x cultivar interaction; P≤0.05). 191

Figure 4.2: Effect of chemical desiccant treatment on physiological stage at harvest for two faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Chemical desiccant x cultivar interaction; P≤0.01). 191

Figure 4.3: Effect of desiccant application date on physiological stage at harvest for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.01). 192

Figure 4.4: Effect of desiccant application date on yield for three chemical desiccant treatments grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.05). 192

Figure 4.5: Effect of desiccant application date on yield for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.05). 193

LIST OF PLATES

CHAPTER TWO

Plate 2.1: Faba bean plots on July 9, 2002 at Legal 113

Plate 2.2: Faba bean plots at Neerlandia in 2001 and 2002 indicating relative growth 114

Plate 2.3: Faba bean plots at Legal in 2001 and 2002 indicating relative growth 115

CHAPTER FOUR

Plate 4.1: Earlibird faba bean plants on August 6, 2002 at Legal 194

Plate 4.2: Faba bean plants on September 5, 2002 at Neerlandia five days after the early desiccant application date and one day after the late desiccant application date 195

Plate 4.3: Faba bean plants on September 17, 2002 at Neerlandia 13 days late desiccation application 196

APPENDIX I

Plate I.1: Chocolate spot ratings 212

List of Abbreviations

AAFC	Agriculture and Agri-Food Canada
AAFRD	Alberta Agriculture Food and Rural Development
ac	acre
ai	active ingredient
appl.	applied
Avg.	average
C	cultivar
CHC	chocolate spot
cm	centimeter
CO_2	carbon dioxide
CV%	coefficient of variation
D	date
DESIC	desiccation application
EC	electrical conductivity
ERS	Edmonton Research Station
FNODES	flowering nodes
g	gram
GDD	growing degree days
glypho	glyphosate
ha	hectar
HARV	harvest
HERB	herbicide application
HGT	height
kg	kilograms
km	kilometer
kPa	kilopascals
KWT	thousand kernel weight
L	liter
L	location
LEAF	leaf drop
m	meter
mm	millimeters
N	nitrogen
Neer	Neerlandia
NS	non-significant
°C	degrees Celsius
P	phosphorous
PHYS	physiological stage at harvest
PLNT	plant population
PPN	pods per node
PPP	pods per plant
PROT	crude protein

ppt'e	precipitation
R	rate
reco.	recommended
S	sulfur
SD	seeding date
se	standard error
SPP	seeds per pod
t	tonne
TIL	tillers
TKW	thousand kernel weight
Y	year
YLD	yield

Chapter 1
Faba bean (*Vicia faba* L.)
Introduction and Objectives

1.1 Distribution and Origin

Faba beans (*Vicia faba* L.) are one of the world's most important legume crops. In 2001, 2.33 million ha of faba beans were grown in approximately 50 countries, producing 3.68 million tonnes of seed (FAO, 2001). China is responsible for 65% of the world's faba bean production while Ethiopia, Egypt, Morocco, and the UK are also major producers. In Africa, Asia, and South America, faba bean seed is used primarily as human food and it provides a significant portion of the protein intake for the Egyptian population. Faba beans have never been a major crop in North America although interest in the crop has increased in recent years. In Europe, Canada, and Australia, most production is used for animal feed with a small portion being used as fresh, canned, or frozen vegetables (Jellis et al., 1998).

The exact geographical origin of the crop remains unknown. Hanelt (1972a) concluded that cultivation of the crop began in the Near East, between Afghanistan and the Eastern Mediterranean, during the period 7000-4000 BC. However, faba beans are not considered to be one of the first domesticated crops due to the scarcity of faba bean seeds found in the archaeological remains of the Near East (Bond et al., 1985). Cubero (1974) proposed that human transmission of the crop spread out from the Near East in four directions. This transmission spread

the crop west to Mediterranean regions, north to Europe, south to Egypt and Mesopotamia, and finally east to India.

1.2 Taxonomy

Faba bean is a member of the Leguminosae family. It belongs to the section *Faba* and the genus *Vicia*. Other species within the *Vicia* genus include *V. narbonensis, V. hyaeniscumus,* and *V. galilaea* (Ladizinsky, 1975). Faba bean has six large chromosomes (n=6) and is the most genetically isolated of the *Vicia* species. Other species in the *Vicia* genus have seven chromosomes (n=7) and have not been successfully crossed with *V. faba* (Schafer, 1973; Yamamoto, 1980). Morphologically, faba bean differs from other *Vicia* species in its lack of tendrils (Bond et al., 1985; Kay, 1979).

Within *Vicia faba*, there has been much controversy regarding intraspecific (within the species) classification. One commonly used system was developed by Muratova (1931) and it recognizes distinct groups based mainly on seed size (Figure 1.1). Hanelt (1972b) suggested that *paucijuga* is a geographical race of the subspecies *minor*. However, Cubero (1974) determined a simpler classification system with four sub-species or botanical varieties of faba bean. They are *Vicia faba minor* (tic bean), *V. faba equine* (horse bean), *V. faba major* (broad bean), and *V. faba paucijuga*. The botanical varieties are distinguished primarily based on seed size and there are no fertility barriers between them.

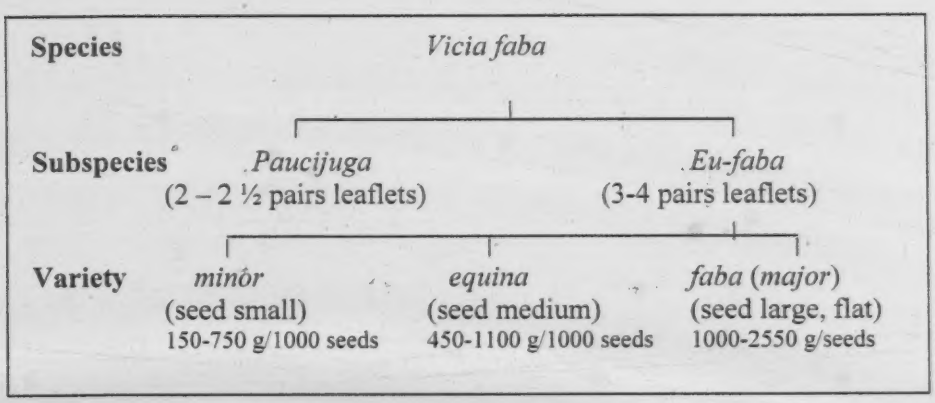

Figure 1.1 Intraspecific classification of *Vicia faba* according to Muratova (1931).

Vicia faba L. has many common names in the English language, however, the different names often refer to a particular botanical variety rather than the species (Bond et al., 1985). The majority of faba beans grown as grain legumes are *Vicia faba* var. *equina* and *Vicia faba* var. *minor* (Knott et al., 1994). *Vicia faba* var. *major* is commonly known as broad bean which is harvested green and consumed as a vegetable crop. However, *Vicia faba* L. can be known as horse, longpod, tick, Egyptian, pigeon, winter, garden, Spanish, Windsor, Vicia, and common beans in various parts of the world. The name 'faba bean' has been widely accepted to refer to the whole species in attempts to lessen confusion (Bond et al., 1985).

1.3 Cultivars

There are two types of faba beans; winter seeded and spring seeded cultivars. Most winter seeded faba beans belong to the *Vicia faba* var. *equina* sub-species (Knott et al., 1994). These cultivars tend to be indeterminate, tall and have the ability to produce several tillers. The winter seeded faba beans also tend to lodge and are susceptible to the fungal disease chocolate spot.

Traditionally, spring sown faba bean cultivars are indeterminate, tall and late maturing (McEwan and Yeoman, 1989). However, since 1986, new cultivars have been developed that are earlier and shorter than traditional faba bean cultivars. There have been some determinate spring sown cultivars produced, but these require a higher seeding rate and are also susceptible to the fungal disease chocolate spot (Knott et al., 1994). Despite the problems with determinate mutants, breeding programs are attempting to incorporate this characteristic (Lopetinsky, K.J. personal communication, 2002).

Faba bean is a relatively new crop in western Canada and therefore, only a few cultivars are available (Park, 1993). The majority of the faba bean cultivars grown in Canada arose from European breeding programs. Canadian breeding programs began in the 1980s, however, with the decline in the faba bean industry breeding efforts declined. A small breeding program has been initiated at the Crop Development Centre, University of Saskatchewan, to breed faba beans for western Canada. The program is a collaboration with Alberta Agriculture, Food and Rural Development (AAFRD) and Agriculture and Agri-food Canada (AAFC). There are

two main goals for this breeding program. One is to develop a small seeded, low tannin variety for animal feed or silage and the other is to develop a large seeded variety of appropriate color and shape for Middle Eastern human consumption markets (Warkentin, T. personal communication, February 28, 2003). In both cases, the breeding program is attempting to achieve varieties that are early maturing and disease resistant.

1.4 Morphology

Faba bean is an annual upright herb, ranging in height from 60-180cm. These robust and leafy plants have thick, square, hollow stems (Knott et al., 1994). Basal branching/tillering occurs but it varies with the cultivar and agronomic practices. Leaves are alternate-pinnate and consist of two to six leaflets. The leaflets are entire, oval shaped, and terminate in a small point, thought to be a rudimentary tendril (Kay, 1979). Stipules are usually toothed (Knott et al., 1994). Faba bean is unusual among the genus *Vicia* in that it lacks tendrils (Bond et al., 1985; Kay, 1979).

Faba bean has a well developed tap-root system with extensive lateral branching (Kay, 1979). The tap root and lateral roots often bear clusters of lobed nodules containing the nitrogen fixing bacteria, *Rhizobium leguminosarum* (Knott et al., 1994, Bond et al., 1985).

The 2.5-4 cm long flowers are borne in the leaf axils on short axillary racemes (Kay, 1979). Racemes contain two to six flowers (Knott et al., 1994). The

corolla is made up of five petals – the standard, two wing petals and a keel which is formed from the two lower petals (Bond and Poulsen, 1983). Flower color can be pure white, or have anthocyanin pigmentation making the sepals and standard petals vary in color from purple to pink. Many cultivars have black or brown melanin spots on the two wing petals.

Faba bean pods are green and fleshy with a pointed beak (Kay, 1979). At the immature stage pods have a white, velvety interior. As the pod matures, it turns brown to black and becomes tough and hard. Seed numbers vary between two to eight seeds per pod and seeds vary in size, shape, and color depending on the variety (Knott et al., 1994). Immature seeds are usually cream or blue grey/green, however, bright lime green seeds also exist (Knott et al., 1994). Mature seeds can be cream, buff, brown, red, purple, brown, black, or green.

1.5 Worldwide Uses

There are six worldwide uses of the crop; dry seed for feed, dry seed for food, processing of dry seed, immature seeds as a vegetable, whole-plant use, and crop residue use. Faba beans are used as feed for swine, poultry, cattle, sheep, and in some areas to feed domestic pigeons (Bond et al., 1985). Tannin-free faba beans have improved feed value for monogastric animals (Ford and Hewitt, 1980). Dry faba bean seed is used for human food in many different ways. In Egypt, faba beans are a major part of the diet. The dried beans are soaked, cooked, and seasoned (Hawtin, 1980). In other areas, flour is made from the faba beans (Bond

et al., 1985). Recently, faba beans have been fried, salted, and used as a snack food (Moreno and Cubero, 1982). Faba beans are eaten as a fresh or cooked vegetable in all areas of the world (Bond et al., 1985). Only immature, tannin-free faba beans are used in the canning process because they do not discolor when cooked (Bond et al., 1985). Whole faba bean plants are used for green manure or livestock feed. Some of the crop residues are used for animal feed, fuel, or in brick making (Bond et al., 1985).

Worldwide, production is decreasing due to low and unstable yields. However, it is still an important crop, which provides a break for cereal systems by decreasing crop input costs, decreasing diseases, improving soil conditions, and decreasing weed populations (Hebblethwaite, 1983).

1.6 Agronomic Practices

Faba bean production is widespread throughout temperate and sub-tropical regions of the world and production practices vary depending on location (Knott et al., 1994). Faba beans are generally suited to cool soil conditions and optimum growth requires average temperatures of 18-27°C over the growing season (Kay, 1979). They are specifically sensitive to high and low temperatures during pollination and fertilization (Jellis et al., 1998). Along with these temperature requirements, faba beans require approximately 650-1000 mm precipitation per year. These high moisture requirements are necessary, as faba beans have a

relatively shallow root system making them poorly adapted to drought (Day and Legg, 1983). Excess water conditions may also cause stress (Bond et al., 1985).

The two basic faba bean types, winter cultivars and spring cultivars, each require different production techniques. Spring seeded cultivars require 90-120 days to mature while winter cultivars require approximately 150-210 days (Kay, 1979). The production area of winter cultivars is limited to warmer climates as they can only tolerate temperatures down to -12°C (Bond et al., 1985). Spring sown cultivars are typically planted as early as possible in the spring while winter sown cultivars can be planted from September to early December (Knott et al., 1994).

Faba bean seed is large and can be placed at a depth of 7.5 to 10cm into a moist, firm, weed-free seed bed (Kay, 1979). Deep seeding is necessary to provide good moisture conditions for germination. Seeding rates vary with cultivars but target plant populations vary between 15 to 60 plants m^{-2} (Bond et al., 1985). Typically, higher plant densities are used for small seeded spring types (40 plants m^{-2}) while the lower plant densities are used for larger seeded or winter cultivars (18 plants m^{-2}) (Knott et al., 1994). Row spacing can vary from 15 to 60 cm, but typical row widths are 20 cm.

Immature faba bean plants are poor competitors, so weed control is essential. In subsistence agricultural systems, weed control is achieved with implements pulled by draft animals or by hand hoeing (Bond et al., 1985). Weed control in modern agricultural systems depends on both cultural practices and

herbicides (Knott et al., 1994). Cultural control methods involve seeding into a relatively weed free seed bed followed by pre-emergence harrowing. Post emergence harrowing can be used to control weeds for winter faba beans. Chemical weed control is available for the majority of weed problems and can achieve the same or better results compared to cultivation.

One of the main disease problems of faba bean is chocolate spot (Bond et al., 1985). Chocolate spot can cause severe yield losses in winter seeded faba beans. Some of the other prevalent fungal diseases include *Ascochyta*, *Uromyces, Sclerotinia,* and *Fusarium*. In terms of insect pests aphids, particularly the black bean aphid *Aphis fabae,* and nematodes are the main problems. Other insect pests of faba bean exist but they are rarely of concern (Cammell and Way, 1983). The parasitic weed broomrape, *Orobanche crenata*, causes significant crop losses in the Mediterranean (Bond et al., 1983).

In most modern agriculture systems, the fully mature faba bean crop is harvested with a combine (Hebblethwaite et al., 1983). Plants may be combined directly, with or without desiccation, either standing or from a windrow. Typically, combining is done when pods are dry and black, the seed has a moisture content of 16 – 20 %, and less than 10% of the stems are green (Knott et al., 1994). It is recommended that faba bean seed is dried to 14 – 16% moisture content before storage.

In 1972, the first commercial faba bean production began in western Canada (Faba Bean Production in Saskatchewan, 1990). Since then, acreage in

western Canada has fluctuated widely. In the 1990's the acreage of faba beans harvested in Alberta was less than 3000 acres per year (Anderson et al., 2003).

Because faba bean is a relatively new crop in western Canada, most information about the crop is based on studies from outside of Canada, particularly Europe.

1.6.1 Nitrogen Fixation Benefits

Faba beans have the ability to form a symbiotic relationship with the nitrogen fixing bacteria, *Rhizobium leguminosarum* (Roughley et al., 1983). Nutman (1976) found that 45-552 kg N/ha are fixed by this symbiotic relationship. The amount of nitrogen fixed varies due to the effectiveness of the *Rhizobium* strain, the genetics of the host plant, agronomic practices, and the environmental conditions (Roughley et al., 1983). In some areas, soils have no natural populations of *R. leguminosarum* therefore, inoculation of the seed or the soil is required (Knott et al., 1994). The nitrogen fixation is so effective that the application of nitrogen fertilizer to faba bean crops is not recommended as it will decrease nitrogen fixation of the *Rhizobia* bacteria.

A single faba bean plant can have more than 1000 nodules (Fryson, 1981). Nodule production begins shortly after germination and nitrogen fixation begins when the first foliage leaf (node 3) is fully expanded. The upper part of the tap root can be entirely covered with large nodules. These large nodules can branch and are up to 1 centimeter in length. Nodules found on lateral roots are usually smaller, but as the plant ages, these smaller nodules become the main sites of nitrogen fixation.

Biological nitrogen fixation by *Rhizobia* bacteria eliminates the requirement for nitrogen fertilizer in faba bean production. This cuts production costs, by saving the cost of nitrogen fertilizer and the fuel cost of distributing and incorporating nitrogen fertilizer (Roughley et al., 1983). The benefits of nitrogen fixation associated with faba bean may lead to increased use of the crop in rotations as fertilizers become more expensive.

1.6.2 Seeding Date

Internationally, faba beans are seeded in either spring or autumn. Autumn sowing tends to produce yields between 0.25 to 3 t/ha more than spring sowing (Hebblethwaite et al., 1977). However, widespread use of autumn sowing is limited by severe winter conditions (Hebblethwaite et al., 1983).

In Canada, where winters are severe, faba bean crops must be planted in the spring. The recommended sowing date in Canada is from early to mid-May due to the cold early springs and late spring frosts (Rowland, 1978). Park and Lopetinsky (1999) recommend that faba bean should be seeded by May 7, in Alberta, to ensure adequate time for maturity. Early seeding is required as the majority of faba bean varieties are indeterminate and therefore, require a long growing season. Early seeding is particularly important in years with early fall frosts that can decrease yield and quality (Evans and Slinkard, 1975).

Unfortunately, early seeding can expose the crop to an increased risk of spring frost damage (Thompson and Taylor, 1977; Knott et al., 1994). However, the risk of aphid damage, drought stress, poor weed control with soil-acting

herbicides, seed-bed drying out, late maturity, and late harvest increase with delayed seeding (Hebblethwaite et al., 1977; Knott et al., 1994). Besides these problems, late seeding can coincide with high temperatures at the time of flower and pod set (Hebblethwaite et al., 1983). Temperatures exceeding 27°C at the time of flowering are associated with blossom drop and seed set failure (Kay, 1979). In addition to problems with flowering, late seeded faba beans develop maximum leaf area too late to make the most use of long days in late June and July (Hebblethwaite et al., 1983).

Numerous authors have found seeding date to strongly influence seed yield in faba bean (Kondra, 1975; Rowland, 1978; Martiniello and Ciola, 1995). Delaying seeding reduces total dry matter and harvest index (McVetty et al., 1986). Harvest index is affected by reductions in the number of pods per plant (Baldwin, 1980; McVetty et al., 1986). Besides reduction in pod number, Marcellos and Constable (1986) found late seeding to result in shorter vegetative and pod filling stages which translated into smaller plants and reduced yields. Baldwin (1980) also found delayed seeding reduced pods per plant and mean seed yields. Although delayed seeding reduces yield, seed protein levels are largely unaffected (Rowland, 1978; McVetty et al., 1986).

1.6.3 Seeding Rate

Plant density is one of the primary yield components of seed crops. In general, yield increases with increasing plant density up to a point and then declines at extremely high plant densities (Forbes and Watson, 1994). Crops that

produce few or no tillers tend to increase yield gradually with increasing plant density. On the other hand, crops that are more plastic and tiller profusely will attain maximum yields at relatively low plant densities. For these plants further increases in plant density will not greatly affect yield.

Spring seeded faba beans have less tillering capacity than winter seeded faba beans (Hebblethwaite et al., 1983; Knott et al., 1994). They are, therefore, less able to compensate for low plant populations and higher seeding rates are required to obtain optimum plant densities. Studies in the UK have shown that increasing plant populations of spring seeded faba beans from 12 to 86 plants m^{-2} gave a diminishing positive yield response for both large seeded (680mg $seed^{-1}$) and small seeded (454mg $seed^{-1}$) faba beans. The large seeded faba beans tended to reach a yield plateau at lower plant populations than the small seeded faba beans (Ingram and Hebblethwaite, 1976). Kondra (1975) examined the effect of seeding rate on yield in Alberta. He examined three seeding rates (100, 150 and 200 kg ha^{-1}) and found that a low seeding rate of 100 kg ha^{-1} produced the lowest yield. The 150 and 200 kg ha^{-1} seeding rates showed higher yields than the 100 kg ha^{-1} seeding rate, however, no significant yield differences were observed between the two higher seeding rates indicating, a diminishing positive yield response.

Changes in seeding rate affect yield components. As seeding rate increases, tillering and the number of pods per plant decrease (Thompson and Taylor, 1977; Knott et al., 1994). However, seed size and number of seeds per pod have little response to increasing plant populations (Thompson and Taylor, 1977). Plant

height is relatively unaffected by increased plant density, but there is a trend towards increased lodging at very high densities (Bengtsson and Bingefors, 1975; Knott et al., 1994).

In England, optimum yields of spring seeded faba bean were achieved with a final plant population of 40 plants m^{-2} (Knott et al., 1994). A seeding rate of 40 plants m^{-2} is also recommended in Alberta (Park and Lopetinsky, 1999). Studies conducted in England found that under fertile soil conditions, a slightly lower seeding rate may be acceptable, but for dry conditions a slightly higher seeding rate is recommended (Knott et al., 1994).

1.6.4 Row Spacing

Before the advent of herbicides, faba bean was seeded with row spacings of 45 cm to allow for mechanical cultivation (Knott et al., 1994). It is now recommended that a row spacing of 20 cm or less be used in production systems using chemical weed control. Boyd et al. (1952) suggested that the narrow row spacing helps the crop to suppress weed growth.

Experiments conducted in the UK found that the yield of spring seeded faba beans increased as row spacing was reduced (Ingram and Hebblethwaite, 1976). These experiments found yield increases to occur in 29 out of 34 experiments and the yield increased 0.35% per centimeter, as row spacing decreased from 58 to 18 cm. Research conducted in Sweden (Bengtsson and Bingefors, 1975), Denmark (Christensen, 1974), Canada (Kondra, 1975), and Italy (Bonari and Macchia, 1975) found similar results. In a collective summary of the above research, it was found

that yields increased by 0.42% per centimeter, as row spacing decreased from 60-75 to 12-18 cm. The experiment conducted in Canada, by Kondra (1975), specifically found that yields increased with a decrease in row spacing from 31 to 15 cm.

1.6.5 Yield Components

Yield component analysis evaluates the relative contribution of various crop components to total yield (Fraser and Eaton, 1983). The five main components of yield for faba bean, commonly included in this analysis are; number of plants per unit area, number of fertile nodes per plant, number of pods per fertile node, the number of seeds per pod, and average seed weight (Thompson and Taylor, 1977). The environment and growing conditions can influence the relative yield component contributions in other crops (Spaner et al., 2000).

The first yield component, number of plants per unit area or plant density is a function of the initial seeding rate, seedling mortality, and the number of seedlings that survive to maturity (Forbes and Watson, 1994). Seedling mortality accounts for most plant population decreases, and therefore this yield component is set very early in the growing season (Forbes and Watson, 1994). Subsequent plant losses from pests, diseases, and environmental stress can continue to reduce plant density throughout the growing season (Hay and Walker, 1989).

The number of fertile or pod-bearing nodes per plant is the second yield component. This factor was shown to be the least stable yield component in experiments conducted, on faba beans, by Thompson and Taylor (1977). In

contrast to this, other experiments have shown that various cultural inputs and differences between years did not result in the number of pod-bearing nodes being more variable than other yield components (Dantuma and Thompson, 1983). Number of pod-bearing nodes per plant is also a function of the number of tillers produced, the number of tillers which are fertile, and finally the number of fertile tillers which survive to produce seed (Forbes and Watson, 1994).

Number of pods per pod-bearing node is the third component. Increasing plant density has been shown to cause a reduction in the number of pods per pod-bearing nodes (Thompson and Taylor, 1977). In many studies, the second and third components, the product of pod-bearing nodes per plant and pods per pod-bearing node is combined to give the number of pods per plant.

The number of seeds per pod has proven to be one of the most stable components for a given cultivar (Dantuma and Thompson, 1983). Thompson and Taylor (1977) found this component to be relatively stable regardless of seeding date and plant density. In a later study, Thompson and Taylor (1981) found this component to be unaffected by light competition. Despite this being the most stable component, the number of seeds per pod varies considerably within a plant, with lower pods having more seeds than upper pods where it is not unusual to find shriveled ovules (Adcock and Lawes, 1976). Number of seeds per pod can vary from less than two to eight depending on the cultivar (Chapman, 1981). Usually, plants with larger seeds tend to have more seeds per pod and smaller seeded varieties tend to have fewer seeds per pod.

The final yield component is the average seed weight. This component varies significantly between cultivars and within a cultivar depending on environmental conditions (Picard and Berthelem, 1981). There have been many different responses of seed weight to seeding rate. Hodgson and Blackman (1956), and Day et al., (1979) found that seed size remained constant as seeding rates increased from approximately 20 to 60 plants m^{-2}. McVetty et al. (1986), and Sprent et al. (1977) found seed size decreased as seeding rate increased. Thompson and Taylor (1977) found seed size increased as seeding rate increased from 10 to 70 plants m^{-2}.

The maximum yield potential is then the product of plant density, number of pod-bearing nodes per plant, number of pods per pod-bearing node, number of seeds per pod and average seed weight (Thompson and Taylor, 1977). Maximum yield potential will then be decreased by plant death, flower and pod abscission, and ovule abortion (Anderson et al., 1986).

1.6.6 Disease Problems

There are a number of fungal diseases that may decrease the yield and quality of a faba bean crop. The major diseases causing yield reduction are chocolate spot, Ascochyta blight, Sclerotinia stem rot, Fusarium root and foot rot, and rust.

1.6.6.1 Chocolate Spot

Chocolate spot is the most devastating and widespread disease of faba bean. The disease is caused by *Botrytis fabae* and *Botrytis cinerea* (Sardina, 1931) and

has reduced yields by 50-100% in China (Yi, 1986). In addition to yield losses, seed from infected pods are blemished and may not be saleable for human consumption. Damage tends to be most frequent in humid areas of the world, with winter sown faba beans being more susceptible to the disease than spring sown varieties. Bernier (1975) reported that chocolate spot is present in Canada, but it is not a major disease problem and does not contribute to crop losses.

Aggressive chocolate spot infections require a high inoculum density, rainfall, high humidity, lack of wind, and a temperature range between 15-20°C (Harrison, 1980). Plants weakened by acidic soil, nutrient deficiencies, waterlogging, frost damage, and high plant densities are predisposed to attack (Ingram and Hebblethwaite, 1976).

A four year crop rotation should be used to control the disease (Jellis et al., 1998). Crop debris should be burnt or deeply plowed to reduce inoculum. In addition, seeding dates can be altered to reduce the risk of frost damage. The disease can also be controlled by using moderate seeding rates to decrease humidity problems associated with high plant densities (Ingram and Hebblethwaite, 1976).

Foliar fungicides are necessary to prevent serious infections from developing and they should be applied at the onset of flowering with a second application three to four weeks later (Knott et al., 1994). Some work has been done with breeding disease resistant faba bean lines. Resistance has been transferred to faba bean populations in Egypt and Southern Australia (Luminis Pty Ltd., 1994).

However, transfer of resistance to winter sown faba beans in England and France has not been successful (Kararah et al., 1991).

1.6.6.2 Ascochyta Blight

Ascochyta blight, caused by *Ascochyta fabae,* is found in Northern Europe, England, Canada, the Middle East, North Africa, China, and the former USSR (Gaunt, 1983). Most economic damage is confined to local outbreaks, and in many years the disease is non-destructive.

The disease is primarily seed borne so planting disease free seed is the best control method (Jellis et al., 1998). Avoiding faba bean crop debris and volunteer plants will help reduce straw-borne inoculum. The disease is most prevalent on winter sown faba beans, and early seeded winter crops tend to develop lesions before winter, which can cause considerable damage. Therefore, winter sown crops should be planted later in the season (Jellis et al., 1998).

Chemical seed treatments are recommended, but effective control requires that the seed treatment be used in combination with a foliar fungicide spray (Knott et al., 1994). Some non-systemic, foliar sprays have been found to reduce disease incidence and seed infection, but multiple spray applications are necessary (Kharbanda and Bernier, 1979).

1.6.6.3 Rust

Rust, caused by *Uromyces viciae-fabae*, is widely distributed and important in most faba bean growing areas. Moderate infections can reduce yields up to 30% but in severe cases, rust can cause 70-80% yield losses in faba bean crops (Lang et

al., 1993). Recently, the disease has become more frequent and severe in the UK (Knott et al., 1994). Rust reduces yield by reducing individual seed weight (Williams, 1978) and the number of pods per plant (Sache and Zadoks, 1995).

In terms of cultural control, crop debris should be buried to reduce inoculum. The disease is also more prevalent on spring seeded crops, so switching to winter sown faba beans is an option, however, winter sown varieties are susceptible to numerous other diseases (Jellis et al., 1998). Foliar fungicide applications are effective and can result in substantial yield benefits (Marcellos et al., 1995).

1.6.6.4 Sclerotinia Stem Rot

Sclerotinia stem rot, caused by *Sclerotinia trifoliorum* and *S. sclerotiorum*, is common in moist, cool environments (Jellis et al., 1998). It has been reported in North America, Europe, and Mediterranean coastal countries. Plants infected with *Sclerotinia* can die or have extremely low yields, however, the percentage of infected plants is usually low and yields are not significantly reduced. Sclerotinia is not a major problem in faba beans compared to chocolate spot, Ascochyta blight, and rust.

The most effective cultural control methods involve rotation and destroying crop residues to prevent inoculum buildup in the soil (Jellis et al., 1998). Low seeding rates, wide row spacing, and weed control are useful to increase air circulation in the crop (Salt, 1983).

There has been limited use of chemical control of Sclerotinia stem rot in *Vicia faba* (Salt, 1983). A breeding program in Greece has developed four lines with some resistance (Karamanos, 1995).

1.6.6.5 Fusarium Root and Foot Rot

Fusarium rot is the most damaging and widespread root disease of faba bean (Salt, 1983). It can destroy a crop when environmental conditions such as drought or flooded soils have caused reduced root growth. However, this disease causes little damage to unstressed plants. Crop losses are related to reduced plant populations, reduced growth, and yield. If infection occurs early, there is reduced seed size and quality (Jellis et al., 1998). Severe root rot infection reduces the number of roots that can form a symbiotic relationship with *Rhizobia* bacteria, thereby reducing nitrogen fixation, slowing plant development, and reducing seed yield (Hwang et al., 2000a; Hwang et al., 2000b).

Fusarium root and foot rot is caused by several species of *Fusarium* including *F. oxysporum*, *F. solani*, *F. avenaceum,* and *F. graminearum*. *Rhizoctonia solani*, *Pythium* spp., *Phoma* spp., and *Cylindrocarpon destructans* can also contribute to the disease (Jellis et al., 1998). The disease is encouraged by high temperatures and soil moisture. Compacted soil, high temperatures, shortages or excesses of water, damage by insect pests, nematodes, along with fungal and viral diseases all make the plants susceptible to the disease. The disease is always present in the soil, but pathogen attack depends on the presence of susceptible host plants. The most effective and practical control methods for foot rot are aimed at

reducing stress factors, which delay the onset of the disease, and reduce yield losses (Salt, 1983). Seed borne inoculum can be controlled with chemical seed treatments (Jellis et al., 1998). Foliar sprays are not effective against the disease.

1.6.7 Insect Pest Problems

Aphids are the most serious insect pest of faba beans (Cammell and Way, 1983). *Vicia faba* can also be infested with nematodes (*Ditylenchus dispaci*). In Alberta, Lygus bugs have caused quality losses (Lopetinsky and Dosdall, 2000). Other insect pests of faba bean exist but they are rarely of concern (Cammell and Way, 1983).

1.6.7.1 Black Bean Aphid

The black bean aphid, *Aphis fabae*, is the most important insect pest of faba beans and can cause severe crop losses from direct feeding damage (Cammell and Way, 1983). *A. fabae* is a pest in temperate and Mediterranean climates especially, Europe, the Middle East, parts of Asia, Africa, and North and South America.

Aphid colonies develop rapidly, as adults are viviparous (live young) and can produce several wingless nymphs each day (Knott et al., 1994). Aphid attacks develop from the time of flowering onwards. Direct aphid feeding causes the plant to fail to develop and as a result pods do not fill normally. In addition to yield losses, *A. fabae* can transmit viruses to the faba bean plants, although this species is less important in virus transmission than other aphid species (Cammell and Way, 1983).

Spring sown faba beans are susceptible to aphid attack (Cammell and Way, 1983). Early seeding dates, high plant populations, and low levels of nitrogen fertilizer are cultural practices that can reduce aphid attacks. This is because plants in dense stands are less nutritious and have a shorter maturation than plants in sparse stands (Way and Heathcote, 1966). Insecticides can control aphid populations, however, the choice of insecticides is limited to those which will not harm pollinating insects (Knott et al., 1994).

1.6.7.2 Stem Nematode

The stem nematode, *Ditylenchus dipsaci*, is the most damaging nematode to faba beans, especially in cooler regions (Hooper, 1983). Nematodes can multiply to yield reducing densities in certain rotations (Bond et al., 1985). *Ditylenchus dipsaci* can attack oats, onions, sugar beets, peas, strawberries, corn, alfalfa, and many weeds (Knott et al., 1994). The nematodes can also persist in the soil for several years without host plants (Hooper, 1976). Therefore, once a site is infested with *D. dipsaci*, a ten year crop rotation, avoiding all susceptible plants, should be used. Stem nematode can be seed-borne, so clean seed should be planted (Knott et al., 1994). Chemical control of nematodes is not cost effective.

1.6.7.3 Lygus Bugs

Lygus lineolaris, L. borealis, L. elisus, and *L. keltoni* are believe to cause yield and quality losses in faba bean, however, it is not currently known which species targets faba bean (Dixon, 2001). Lygus bugs damage faba bean by feeding directly on maturing seeds within pods causing reductions in yield and quality

(Dixon, 2001). Currently, studies are being conducted by Lopetinsky and Dosdall (2000), investigating the control of Lygus bug infestations with cyhalothrin-lambda (Matador®) in Alberta.

1.6.8 Weed Problems

Faba bean is a poor competitor, especially at the seedling stage so good weed control is necessary for faba bean production (Park and Lopetinsky, 1999). Both cultural and chemical weed control methods exist. A major weed of particular importance, in the Mediterranean, is the parasitic weed broomrape (Cubero, 1983).

1.6.8.1 Cultural Control Methods

The main cultural weed control method is to seed faba bean into a relatively weed free seed bed (Knott et al., 1994). Harrowing prior to emergence is recommended to produce a level surface and to remove young weed seedlings. Post emergence harrowing is used in winter seeded beans to control weeds. This may result in damage to the growing point but winter beans compensate by tillering. Post emergent harrowing is not recommended for spring seeded faba bean because they have a limited tillering ability.

1.6.8.2 Chemical Control Methods

Chemical weed control is available for most weed problems, and is usually superior or equivalent to cultivation (Knott et al., 1994). Pre-sowing herbicides, pre-emergence, and post emergence herbicides can all be used to control weed problems in faba bean. In Alberta, trifluralin (Advance 10G / Bonanza / Rival /

Treflan), ethalfuralin (Edge), bentazon (Basagran), metribuzin (Sencor), diclofop-methyl (Hoegrass 284), and sethoxydim (Poast Ultra) are recommended for use on faba bean (Ali et al., 2001). Other herbicides have been investigated for use in faba bean although no recommendations have been made.

1.6.9 Harvest Management Techniques

Faba bean seed grain is typically harvested with a combine once the crop has matured (Hebblethwaite, 1970). The crop can be swathed and then combined or the crop can dry standing, and then be combined. Typically, combining is done when pods are dry and black, the seed has a moisture content of 16 – 20 % and less than 10% of the stems are green (Knott et al., 1994).

The indeterminate growth habit of faba beans can make harvesting difficult due to uneven ripening (Hebblethwaite, 1970). The bottom pods can be too dry to harvest while upper pods remain too wet. Dry pods are a problem because they can shatter, creating high yield losses (Nash, 1978). Swathing and desiccation have been used to overcome these harvesting difficulties.

Studies conducted in Manitoba (Betts and Morrison, 1980) found that swathing before the 25% black pod stage resulted in decreased yields, decreased seed size and shriveled, discolored seeds. In Saskatchewan, Rowland (1978) found that yield, seed protein content, seed size, and seedling fresh weight stabilized when 30-40% of the plants had their lowest pods turn black. He recommended swathing at this stage to attain the highest yields and acceptable seed quality while minimizing shattering losses.

Chemical desiccation of faba beans, to accelerate plant and seed drying, has not been completely successful (Thompson and Taylor, 1982). Success is limited because the foliage intercepts much of the spray and prevents adequate spray contact on the stem and pods. A dry period, following chemical application, produces the best desiccation results. If precipitation follows chemical application, seed moisture contents increase faster in desiccated than undesiccated plants.

Diquat applied at a rate of 0.4 – 0.6 kg/ha in medium water volumes of 55 L/ha is commonly used for desiccation (Betts and Morrison, 1980). Betts and Morrison (1980) found that diquat applications when at least 25% of the pods had turned black would not result in seed yield or quality losses. Desiccation before this stage may result in reduced yield and quality. Knott et al. (1994) recommends diquat applications at a much later desiccation stage when 90% of the pods are dry and black and most seed is dry.

When comparing dry down techniques of swathing and chemical desiccation with diquat, Betts and Morrison (1980) found that there were fewer shriveled seeds with swathing compared to desiccation. This may be due to swathing drying down a plant more slowly than chemical desiccation. According to Betts and Morrison (1980), diquat resulted in complete leaf kill in 2-4 days, whereas it took 5-10 days with swathing. They suggested that assimilate movement to the seeds is brought to an abrupt halt by desiccation which resulted in the production of more shriveled seeds. Thus, desiccation prior to the 25% black

pod stage is more detrimental to seed quality than early swathing before the 25% black pod stage.

In most countries, it is recommended that faba beans are dried to 14 – 16% moisture content before storage. The large seed size and skin thickness makes it more difficult to artificially dry faba bean seeds compared to smaller seeded grain crops (Hebblethwaite, 1970). This is because moisture has a long way to travel from the center of the seed to the testa (MAFF, 1981). Once moisture reaches the thick seed coat, it can only escape via the micropyle, which increases drying time (Hebblethwaite et al., 1983).

Artificially drying faba bean seeds at high temperatures between 90-100°C can stress the inner and outer areas of the seed which will result in seed cracking (Hebblethwaite, 1970). Cracking, in moist seeds, can result in the development of mold or germination losses. These problems can be overcome by putting the crop through a drier multiple times at temperatures of 38-40°C, for crops with moisture contents below 24%, or at temperatures of 35-38°C, for crops with moisture contents above 24% (McLean, 1980).

1.7 Tannin-Free Faba Bean

Vicia faba seed has a high protein content (26-36% in spring beans and 22-28% in winter beans) (Bond, 1977). However, traditional faba beans contain several anti-nutritional factors which greatly reduce the usefulness of faba bean as a protein source (Marquardt, 1983). The primary anti-nutritional components in

traditional faba beans are condensed tannins, which are located primarily in the testa of the seed (Marquardt et al., 1977, Griffiths and Jones, 1977).

In 1930, Erith first described faba bean cultivars with white flowers. It was later found that these cultivars do not contain condensed tannins in their seed coat (Bond, 1976). This tannin-free characteristic was found to be controlled by two recessive genes (Picard, 1976). Tannin-free faba beans are characterized by a white flower, an absence of pigment on the stipules, absence of anthocyanin on the stem, decreased seed coat weights and higher *in vitro* digestibility compared to tannin-containing cultivars (Crofts et al., 1980).

The testa of faba beans with colored flowers contained 4-8% total phenolics, which is primarily tannin (Griffiths and Jones, 1977). However, the testa of white flowered varieties contained less than 0.6% total phenolics. A study conducted by Marquardt et al. (1978) found 0.2% condensed tannins in the testa of white flowered faba beans. Due to the extremely low levels of condensed tannins, white flowered faba beans are considered tannin-free.

Tannin-containing faba beans have shown to reduce body weight gain, impair feed conversion efficiency, and reduce crude protein digestibility (Marquart et al., 1977; Jansman et al., 1993). Bond (1976) found that colored flowered faba beans had a 4.7% reduction in *in vitro* dry-matter digestibility compared to the white flowered varieties. *In vivo* chicken feeding tests found similar results (Marquardt and Ward, 1979). These studies found that the higher digestibility of the white flowered faba beans is associated with the absence of tannin in the testa.

Bond (1976) found that the seed coats of tannin-free varieties comprise a smaller percentage of the total seed weight compared to tannin-containing varieties. However, this was not found to improve the digestibility of tannin-free varieties.

1.7.1 Agronomic Challenges

Despite the nutritional benefits of tannin-free faba beans, they may require modified production techniques to attain high quality and yield. Previous studies have found that tannin-free faba beans have an increased incidence of seedling disease and emergence problems (Kantar et al., 1996). Seeds from tannin-free cultivars tend to have poor emergence, a higher incidence of testa and cotyledon cracking, a smaller percentage of hard seeds, more rapid water uptake, and greater leaching of solutes: all of which can stimulate fungal growth around germinating seeds. Similar problems have been observed in white seeded and low phenolic cultivars of chickpeas (Knights and Mailer, 1989), peas (Powell, 1989), and French beans (Dickson and Petzold, 1988). Low resistance levels to soil-borne fungi observed in tannin-free faba beans is believed to be associated with the chemical and physical properties of the testa (Kantar et al., 1996).

Emergence problems can be partially reduced with the use of fungicidal seed dressings (Bond and Smith, 1989). However, emergence problems observed in tannin-free faba beans are also believed to be associated with the physical properties of the testa (Kantar et al., 1996). This indicates that a fungicide seed treatment may not be completely effective. If this is the case, seed treatments would increase the cost of production and might not always be effective.

There have been no published agronomic studies (seeding date, seeding rate, desiccation) conducted specifically with tannin-free faba beans. Some studies have investigated emergence and disease problems associated with the tannin-free cultivars.

1.7.2 Fungicidal Properties of Tannins

Poor field emergence of tannin-free cultivars can be reduced with the use of fungicidal seed dressings, which suggests that tannins may have fungicidal properties (Bond and Smith, 1989). The precursors of condensed tannins have been shown to inhibit the hydrolytic enzymes of plant pathogens (Byrde, 1963). For example, the fruit rotting fungus *Sclerotinia fructigena* produces pectinase enzymes, which are inhibited by oxidized tannin precursors (Mace and Howell, 1974). Cotton seedlings have resistance to *Rhizoctonia solani*, which is caused by oxidized tannin precursors inhibiting polygalacturonase produced by the pathogen (Hunter, 1974). The growth of many fungi, yeast, bacteria, and viruses has been shown to be inhibited by tannins (Scalbert, 1991).

Tannin-containing faba beans have tannins and high concentrations of other phenolic compounds in their testa (Kantar et al., 1996). Extracts from the testa of tannin-containing faba beans have been found to display fungicidal properties inhibiting *Fusarium culmorum*, *Phoma medicaginis* var. *pinodella*, *Fusarium solani* and *Fusarium tricinctum* (Kantar et al., 1996). However, it is currently unknown if it is tannins and/or non-tannin phenolics which are inhibiting fungal growth. It is thought that tannins are the primary source of fungal resistance in

tannin-containing faba beans, however, other non-tannin plant phenolics may also be involved (Fawcett and Spencer, 1969; Deschamps, 1989).

The simple solution to decrease emergence problems with tannin-free faba beans is fungicide seed treatments. Studies conducted by Hwang et al. (2000a,b), on field pea and lentil, found that systemic fungicide seed treatments generally improved seedling emergence and decreased root rot severity (Hwang et al., 2000a). However, widespread use of systemic fungicides increases the selective pressure for resistant pathogens and this could threaten the long term usefulness of these fungicides. Hwang et al. (2000a) found the use of high quality seed, early seeding coupled with fungicide use in field pea, was more reliable in combating fungal attacks than any single practice on its own. In relation to tannin-free faba bean production, Kantar et al. (1994) indicated that tannin-free faba beans may develop to a critical stage where the entry of fungal pathogens is resisted. Rapid development to this critical stage was expected when seeding was delayed and soil temperatures were warmer. Therefore, the use of systemic fungicide seed treatments is not the only means of achieving vigorous emergence.

1.7.3 Interaction of Early Planting and Seedling Disease

On the Canadian prairies, crops need to be seeded as early as possible, usually between late April and late May, to maximize yield potential and make the most use of the short growing season (McVetty et al., 1986). In the northern prairie region, mean daily soil temperatures (5cm) increase from 8.7°C on May 1st to 15.7°C by June 1st (Environment Canada Atmospheric Services, 1999). Therefore,

seeding date will influence the microclimate of the germinating seed and seedlings (Adam et al., 1989; Omer et al., 1989).

Experiments conducted in Alberta, on lentil and field pea (both tannin-free crops) investigated the role of soil temperature and seeding date on the severity of root rots caused by *Fusarium* sp. and *Pythium* sp. (Hwang et al., 2000a; Hwang et al., 2000b). They found that emergence was 10-15% lower when field pea was seeded in late May to early June (Hwang et al., 2000a). Emergence was also reduced for late seeded lentils (Hwang et al., 2000b). Emergence problems associated with late spring seeding were unexpected. However, it was concluded that early seeding was successful because the crop germinated and established before soil temperatures were optimal for *Fusarium* sp. and *Pythium* sp. infection (Hwang et al., 2000a; Hwang et al., 2000b).

In Alberta, in early spring, soils are typically saturated and the high soil moisture contents enhance the pathogenicity of *Pythium* spp. (Pieczarka and Abawi, 1978). For most plant species, high soil moisture conditions associated with cool soil temperatures, at early spring seeding dates, increase leaching of nutrients from the seed which reduces seedling vigor and increases seedling decay (Herner, 1986). Therefore early seeding has the potential to cause emergence problems. Kantar et al. (1996) suggested that tannin-free faba beans would have reduced populations when seeded early.

1.8 Research Objectives

There have been no published agronomic studies (seeding date, seeding rate, desiccation) conducted specifically with tannin-free faba beans. The objective of these studies was to determine if tannin-free faba beans could be produced using traditional faba bean production systems used in north central Alberta, or if a modified system is required. To accomplish this objective:

- information was reviewed that is applicable to tannin and tannin-free faba bean seed production (Chapter I).
- the most effective seeding date, seeding rate, and cultivar required for optimum yield and quality was studied (Chapter II),
- yield components of tannin-containing and tannin-free varieties were examined along with their response to seeding date and seeding rate (Chapter III) and,
- desiccation procedures necessary to produce high quality faba bean seed were examined (Chapter IV).

1.9 Literature Cited

Adam, N.M., M.B. McDonald Jr., and P.R. Henderlong. 1989. The influence of seed position, planting and harvest dates on soybean seed quality. Seed Sci. Technology. 17:143-152.

Adcock, M.E. and D.A. Lawes. 1976. Self-fertility and the distribution of seed yield in *Vicia faba* L. Euphytica. 25:89-96.

Ali, S., Calpas, J. and Bourne, J.B., eds., 2001. Crop Protection. Alberta Agriculture, Food and Rural Development Information Package Centre. Edmonton, Alberta, pp. 357-358.

Anderson, M. and Associates. March 2003. Faba Bean Opportunities and Constrains in Alberta. Prepared for Alberta Agriculture, Food and Rural Development. pp.51.

Anderson, W.C., W.A. Haglund, G.W. Eaton and J. Fraser. 1986. Sequential yield component analysis of processing pea. HortScience. 21(1):103-105.

Baldwin, B. 1980. Time of sowing – a major factor influencing the yields or *Vicia faba* in South Australia. FABIS Newsletter. 2:39.

Bengtsson, A and S. Bingefors. 1975. Agronomic experiments with field beans. Effect of sowing date, row spacing and seeding rate. LanthbrHogsk. Med. 229:27-36.

Bernier, C.C. 1975. Diseases of pulse crops and their control. pp. 439-454. *In* J.T. Harapiek (ed.). Oil Seed and Pulse Props in W. Canada. Western Co-operative Fertilizers Ltd., Calgary, Alberta. 703 pp.

Betts, M.F. and I.N. Morrison. 1980. Effects of chemical desiccation versus swathing on seed yield and quality of faba beans (*Vicia faba*). Can. J. Plant Sci. 60:1115-1121.

Bonari, E. and M. Macchia. 1975. Effect of plant density on yield of bean *Vicia faba* L. var. *minor* (Peterm.). Riv. Agron. 9:416-423.

Bond, D.A. 1976. *In vitro* digestibility of the testa in tannin-free field beans (*Vicia faba* L.). J. Agric. Sci. (Camb.) 85: 561-566.

Bond, D.A. 1977. Breeding for zero-tannin and protein yield in field beans (Vicia faba L.). In Protein Quality from Leguminous Crops, pp. 348-360. Pub. No. EUR 5686 N. Commission of the European Communities, Luxembourg.

Bond, D.A., D.A. Lawes, G.C. Hawtin, M.C. Saxena and J.H. Stephens. 1985. Faba bean (*Vicia faba* L.). Grain Legume Crops. 199-265.

Bond, D.A. and M.H. Poulsen. 1983. Pollination. pp.77-101. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Bond, D.A. and D.B. Smith. 1989. Possibilities for the reduction of antinutritional factors in grain legumes by breeding. pp. 285-296. *In* J. Hauisman, T.F.B. van der Poel and I.E. Liener (eds.). Recent Advances of Research in Antinutritional Factors in Legume Seeds. Wageriner, The Netherlands: PUDOC.

Boyd, D.A., G.W. Cooke, H.V. Garner and J.R. Moffatt. 1952. Rothamsted experiments on field beans. 1. Manuring and cultivation of field beans. Fm. Country. 223: 643-644.

Byrde, R.J.W. 1963. Natural inhibitors of fungal enzymes and toxins in disease resistance. pp. 31-47. *In* S. Rich (ed.). Perspectives in biochemical plant pathology. Conn, Agric. Exp. Sta. Bull. pp.663.

Cammell, M.E. and M.J. Way. 1983. Aphid Pests. pp. 315-346. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Chapman, G.P. 1981. Genetic variation within *Vicia faba*. FABIS (June) p. 12.

Christensen, S.P.L. 1974. Various seed rates and row spacings for field beans and inter-row cultivation in field beans. Tidsskrift for Planteavl. 75: 379-388.

Crofts, H.J., L.E. Evans, and P.B.E. McVetty. 1980. Inheritance, characterization and selection of tannin-free faba beans (*Vicia faba* L.). Can. J. Plant Sci. 60:1135-1140.

Cubero, J.I. 1974. On the evolution of *Vicia faba* L. Theoret. Appl. Genet. 45: 47-51. In Hebblethwaite.

Cubero, J.I. 1983. Parasitic diseases in *Vicia faba* L. with special reference to broomrape (*Orobanche crenata* Forsk.). pp. 493-521. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Dantuma, G. and R. Thompson. 1983. Whole-crop physiology and yield components. pp. 143-158. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Day, W. and B.J. Legg. 1983. Water relations and irrigation response. pp. 217-231. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Day, J.M., R.J. Roughley, and J.F. Witty. 1979. The effect of planting density, inorganic nitrogen fertilizer and supplementary carbon dioxide on yield of *Vicia faba* L. J. Agric. Sci., Camb. 93:629-633.

Deschamps, A.M. 1989. Microbial degradation of tannin and related compounds. pp. 559-567. In N.G. Lewis and M.G. Paice eds., Plant Cell Wall Polymers: Biogenesis and Biodegradation. American Chemical Society, Washington DC.

Dickson, M.H. and R. Petzold. 1988. Deleterious effect of white seed due to p gene in beans. J. American Society of Horticultural Science. 113:111-114.

Dixon, W.N. 2001. Featured Creatures. University of Florida, Department of Entomology and Nematology. Electronic reference. Retrieved July 29, 2002, from http://creatures.ifas.ufl.edu/trees/tarnished_plant_bug.htm.

Environment Canada Atmospheric Services. 1999. Weather record for 1968-1999. Environment Canada, Edmonton, AB.

Erith, A.G. 1930. The inheritance of color, size, form of seeds and flower color in *Vicia faba* L. Genetica. 13:477-510.

Evans, L.E. and Slinkard, A.E. 1975. Production of Pulse Crops in Canada. *In* J.T. Harapiak, ed. Oilseed and pulse crops in western Canada – a symposium. Western Cooperative Fertilizers Ltd.

FAO. 2001. Food and Agriculture Organization, Production Yearbook, Statistics Series 125, Rome, Table 33, p. 101.

Faba Bean Production in Saskatchewan. 1990. Electronic references. Retrieved January 29, 2003, from http://www.agr.gov.sk.ca/docs/crops/pulses/scf0190.asp

Fawcett, C.H. and D.M. Spencer. 1969. Natural antifungal compounds. pp. 637-669. *In* D.C. Torgeson (ed.) Fungicides: An advanced Treatise Vol. 2, Academic Press, New York.

Forbes, J.C. and R.D. Watson. 1994. Plants in agriculture. Cambridge University Press, Great Britain. pp.355.

Ford, J.E. and D. Hewitt. 1980. pp. 125-139. *In* Bond, D.A. (ed.) *Vicia faba*: Feeding Value, Processing and Viruses. The Hauge: Martinus Nijhoff.

Fraser, J. and G.W. Eaton. 1983. Applications of yield component analysis to crop research. Field Crop Abstr. 36: 787-797.

Fryson, A. 1981. Effects of low temperature on the development and functioning of root nodules of *Vicia faba* L. Ph.D. Thesis, University of Dundee. *In* Roughley, R.J., J.I. Sprent and J.M. Day. 1983. Nitrogen Fixation. pp. 233-260. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Gaunt, R.E. 1983. Shoot diseases caused by fungal pathogens. pp. 463-492. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Griffiths, D.W., and D.I.H. Jones. 1977. Cellulase inhibition by tannins in the testa of field beans (*Vicia faba*). J. Sci. Fd. Agric. 28:983-989.

Hanelt, P. 1972a. Zur Geschichte des Anbaues von *Vicia faba* und ihrer verschiedenen Formen. Kulturpflanze. 20: 209-223. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Hanelt, P. 1972b. Die infraspezifische Variabilitat von *Vicia faba* und ihre Gliederung. Kulturpflanze. 20: 75-128. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Harrison, J.G. 1980. Effects of environmental factors on growth of lesions on field bean leaves by *Botrytis fabae*. Ann. Appl. Biol. 95:53-61.

Hawtin, L. 1980. Faba Bean Cook Book. Aleppo, Syria: ICARDA. *In* Bond, D.A. (ed.) *Vicia faba*: Feeding Value, Processing and Viruses. The Hauge: Martinus Nijhoff.

Hay, R.K.M and A.J. Walker. 1989. An introduction to the physiology of crop yield. Longman Scientific and Technical co published with John Wiley and Sons. Inc. New York.

Hebblethwaite, P.D. 1970. Production, marketing and utilization of the field bean. MSc thesis, University College of North Wales. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Hebblethwaite, P.D. (ed.). 1983. The Faba Bean (*Vicia faba* L.). Butterworths, London. 573 pp.

Hebblethwaite, P.D., G.C. Hawtin, and P.J.W. Lutman. 1983. The husbandry of establishment and maintenance. pp.271-312. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Hebblethwaite, P.D., J. Ingram, R.K. Scott, and J. Elliott. 1977. Some factors influencing yield variation of field beans (*Vicia faba* L.). pp. 20-27. *In* R. Thompson (ed.). Proceedings, Symposium on the Production, Processing and Utilization of the Field Bean (*Vicia faba* L.). Bulletin No. 15, Scottish Horticultural Research Institute, Invergowrie.

Herner, R.C. 1986. Germination under cold soil conditions. Hortscience. 21:1118-1122.

Hodgson, G.L. and G.E. Blackman. 1956. An analysis of the influence of plant density on the growth of Vicia faba. I. The influence of density of the pattern of development. J. Experimental Botany. 7:147-165.

Hooper, D.J. 1976. Stem eelworm (*Ditylenchus dipsaci*) on field beans (*Vicia faba*). *In* Rothamsted Experimental Station Report for 1975, Part 1, pp. 202-203. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Hooper, D.J. 1983. Nematode pests of *Vicia faba* L. p 347- 370. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Hunter, R.E. 1974. Inactivation of pectic enzymes by polyphenols in cotton seedlings of different ages infected with *Rhizoctonia solani*. Physiol. Plant Pathol.

Hwang, S.F., B.D. Gossen, G.D. Turnbull, K.F. Chang, R.J. Howard and A.G. Thomas. 2000a. Seeding date, temperature, and seed treatment affect pythium seedling blight of field pea. Can. J. Plant Pathol. 22:392-399.

Hwang, S.F., B.D. Gossen, G.D. Turnbull, K.F. Chang, R.J. Howard and A.G. Thomas. 2000b. Effect of temperature, seeding date, fungicide seed treatment and inoculation with *Fusarium avenaceum* on seedling survival, root rot severity and yield of lentil. Can. J. Plant Sci. 80:899-907.

Ingram, J. and P.D. Hebblethwaite. 1976. Optimum economic seeding rates in spring and autumn sown field beans. Agric. Progress. 51:27-32.

Jansman, A.J.M., M.W.A. Verstegen, and J. Husiman. 1993. Effects of dietary inclusion of hulls of faba beans (*Vicia faba* L.) with a low and high tannin content of condensed tannins on digestion and some physiological parameters in piglets. Animal feed science and technology. 43:239-257.

Jellis, G.J., D.A. Bond and R.E. Boulton. 1998. Diseases of faba bean. pp. 371-422. *In* P.J. Allen and J.M. Lenne. The Pathology of Food and Pasture Legumes. CAB International, New York, NY.

Kantar, F., P.D. Hebblethwaite, and C.J. Pilbeam. 1994. Studies on the establishment of white-flowered faba bean (*Vicia faba*). Journal of Agricultural Science, Cambridge. 123:341-348.

Kantar, F., C.J. Pilbeam, and P.D. Hebblethwaite. 1996. Effect of tannin content of faba bean (*Vicia faba*) seed on seed vigor, germination and field emergence. Ann. appl. Biol. 128:85-93.

Karamanos, A.J. 1995. Varietal improvement in faba beans: Greece. Grain Legumes. 8:17.

Kararah, M.A., Mohamed, H.A., Aly, H.Y. and Habib, W.F. 1991. Nature of resistance in faba beans to *Botrytis fabae* Sard. Egyptian Journal of Agricultural Research. 69: 651-662.

Kay, D.E. 1979. Crop and Product Digest No. 3 - Food Legumes. Tropical Products Institute. London. 435 pp.

Kharbanda, P.D., and C.C. Bernier. 1979. Effectiveness of seed and foliar applications of fungicides to control ascochyta blight of faba beans. Can. J. Pl. Sci. 59:661-666.

Knights, E.J. and R.J. Mailer. 1989. Association of seed type and color with establishment, yield and seed quality in chickpeas (*Cicer arietinum*). J. of Agric. Sci. Cambridge. 113: 325-330.

Knott, C.M., A.J. Biddle and B.M. McKneown. 1994. PGRO Field Bean Handbook. Processors and Growers Research Organization, Peterborough, UK.

Kondra, Z.P. 1975. Effect of row spacing, seeding rate and date on seeding of faba beans. Can. J. Pl. Sci. 55:211-214.

Ladizinsky, G. 1975. On the origin of broad bean *Vicia faba* L. Israel J. Bot. 24: 80-88.

Lang, L.J., Z.H. Yu, Z.J. Zheng, M.S. Xu, and H.Q. Ying. 1993. Faba bean in China: State of Art Review. International Center for Agricultural Research in Dry Areas. Aleppo, Syria.

Lopetinsky, K.J. and L. Dosdall. 2000. Lygus Bug Control in Faba bean Crops in Northwest Alberta. APG – Zone 3 Progress Report.

Luminis Pty. Ltd. 1994. Variety 'Icarus' Application no. 92-007. Plant Varieties Journal Australia. 7. pp. 7-8, 33

MAFF. 1981. Field beans. Ministry of Agriculture, Fisheries and Food, Booklet 2373, pp 25-27. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Mace, M.E. and C.R. Howell. 1974. Histochemistry and identification of condensed tannin precursors in roots of cotton seedlings. Can. J. Bot., 52: 2423-2426.

Marcellos, H. and G.A. Constable. 1986. Effects of plant density and sowing date on grain yield of faba bean (*Vicia faba* L.) in Northern New South Wales. Aust. J. Exp. Agric. 26:493-6.

Marcellos, H., K.J. Moore, and A. Nikandrow. 1995. Influence of foliar applied fungicides on seed yield of faba bean (*Vicia faba* L.) in northern New South Wales. Australian Journal of Experimental Agriculture. 35:97-102.

Marquardt, R.R. 1983. Antimetabolites in faba beans: metabolic significance. FABIS. 7:1-4.

Marquart, R.R., J.A. McKirdy, and A.T. Ward. 1978. Comparative cell wall constituent levels of tannin-free and tannin-containing cultivars of faba beans (*Vicia faba* L.). Can. J. Animal Sci. 58:775-781.

Marquardt, R.R. and A.T. Ward. 1979. Chick performance as affected by autoclave treatment of tannin-containing and tannin-free cultivars of faba beans. Can. J. Animal Sci. 59:781-789.

Marquardt, R.R., A.T. Ward, L.D. Campbell and P.E. Cansfield. 1977. Purification, identification and characterization of a growth inhibitor in faba beans (*Vicia faba* L. var. *minor*). J. Nutr. 107: 1313-1324.

Martiniello, P. and A. Ciola. 1995. Dry matter and seed yield of Mediterranean annual legume species. Agronomy Journal. 87: 985-993.

McEwan, J. and D.P. Yeoman. 1989. Effects of row spacing and the control of pests and pathogens on four cultivars of spring-sown field beans (*Vicia faba*). Journal of Agricultural Science, Cambridge. 113:365-371.

McLean, K.A. 1980. Drying and Storing Combinable Crops. Farming Press Ltd.; Ipswich. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

McVetty, P.B.E., L.E. Evans and J. Nugent-Rigby. 1986. Response of faba bean (*Vicia faba* L.) to seeding date and seeding rate. Can. J. Plant Sci. 66: 39-44.

Moreno, M.T. and J.I. Cubero. 1982. FABIS 4: 10-13.

Muratova, V.S. 1931. Common Beans (*Vicia faba* L.). Supplement 50, Bull. Appl. Bot. Genet. Pl. Breed. 1-298.

Nash, M.J. 1978. Crop conservation and storage in cool temperate climates. Pergamon Press, Oxford.

Nutman, P.S. 1976. IBP field experiments on nitrogen fixation by nodulated legumes. In Symbiotic Nitrogen fixation in Plants, pp. 211-237. Ed. By P.S. Nutman. Cambridge University Press.

Omer, M.A., V.T. Sapra and R.T. Pacumbaba. 1989. Effect of date of planting, genotype, and source of seed on disease incidence, yield and agronomic performance of soybean. J. Agron. Crop Sci. 163:297-307.

Park, B. 1993. Pulse Production Manual. Alberta Pulse Growers Commission.

Park, B. and K. Lopetinsky. 1999. Pulse Crops in Alberta. Alberta agriculture, Food and Rural Development, Edmonton, AB. pp.123-140.

Picard, J. 1976. Aperçu sur l'hérédité du caractère absence de tanins dans les graines de féverole (*Vicia faba* L.). Ann. Amélior. Plantes 26: 101-106.

Picard, J. and P. Berthelem. 1981. A brief note on yield stability and 1000 grain weight in *Vicia faba*. FABIS 2:20.

Pieczarka, D.J. and G.S. Abawi. 1978. Populations and biology of *Pythium* species associated with snap bean roots and soils in New York. Phytopathology. 68:409-416.

Powell, A.A. 1989. The importance of genetically determined seed coat characteristics to seed quality in grain legumes. Annals of Botany. 63: 169-195.

Roughley, R.J., J.I. Sprent and J.M. Day. 1983. Nitrogen Fixation. pp. 233-260. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Rowland, G.G. 1978. Effects of planting and swathing dates on yield, quality and other characteristics of faba beans (*Vicia faba*) in central Saskatchewan. Can. J. Plant Sci. 58:1-6.

Sache, I. and J.C. Zadoks. 1995. Effect of rust (*Uromyces viciae-fabae*) on yield components of faba bean. Plant Pathology. 44:675-685.

Salt, G.A. 1983. Root diseases of *Vicia faba* L. pp. 393-420. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Sardina, J.R. 1931. Dos nuevas enfermedadas de las Habas. Abstract in Rev. appl. Mycol. 11:346.

Scalbert, A. 1991. Antimicrobial properties of tannins. Phytochemistry. 30: 3875-3883.

Schafer, H.I. 1973. Zur Taxonomieder *Vicia narbonesis*-Gruppe. Kulturpflanze 21: 211-273. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Spaner, D., A.G. Todd and D.B. McKenzie. 2000. The effect of seeding date, seeding rate and N fertilization on winter wheat yield and yield components in eastern Newfoundland. Can. J. Plant Sci. 80: 703-711.

Sprent, J.E., A.M. Bradford, and C. Norton. 1977. Seasonal growth patterns in field beans (*Vicia faba*) as affected by population density, shading and its relationship with soil moisture. J. Agric. Sci. (Camb.) 88:293-301.

Thompson, R. and H. Taylor. 1977. Yield components and cultivar, sowing date and density in field beans (*Vicia faba*). Ann. appl. Biol. 86:313-320.

Thompson, R. and H. Taylor. 1981. Factors limiting growth and yield of *Vicia faba*. pp. 34-45. In R. Thompson (ed.). Proceedings: EEC Seminar, *Vicia faba*: Physiology and Breeding, Wageningen Martinus Nijhoff and Commission of European Communities.

Thompson, R. and H. Taylor. 1982. Prospects for *Vicia faba* L. in North Europe. Outlook on Agriculture. Volume II, No. 3. 127-133.

Way, M.J. and G.D. Heathcote. 1966. Interactions of crop density of field beans, abundance of *Aphis faba* Scop., virus incidence, and aphid control by chemicals. Ann. Appl. Biol. 57:409-423.

Williams, P.H. 1978. Growth of broad beans infected by *Uromyces viciae-fabae*. Annals of Applied Biology. 90:329-334.

Yamamoto, K. 1980. On the interspecific hybrid progenies between *Vicia pilosa* M.B. and *V. amphicarpa* Dorth. Jap. J. Breed. 30:351-357. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Yi, L.X. 1986. Faba bean diseases in China. Faba bean Inf. Serv. Newsl. 15:49-51.

Chapter 2
Effects of Cultivar, Seeding Date and Seeding Rates on Faba Bean Yield and Quality

2.1 Introduction

Faba bean is an annual grain legume that produces seeds containing 26 to 36% protein (Bond, 1977). Traditional faba beans, with colored flowers, contain several anti-nutritional factors which greatly reduce the usefulness of faba beans as a protein source (Marquardt, 1983). The testas of traditional faba beans contain 4-8% total phenolics, primarily tannin, which is the main anti-nutritional component (Griffiths and Jones, 1977). The testa of white flowered cultivars contain less than 0.6% total phenolics and are considered tannin-free. Bond (1976), and Marquardt and Ward (1979) found that white flowered faba beans have a 4.7% higher digestibility than traditional faba beans. This improvement in digestibility is associated with the absence of tannin in the testa, making tannin-free faba beans a useful protein source for both humans and livestock.

Despite the nutritional benefits of tannin-free faba beans, they may require modified agronomic techniques to attain high seed quality and yield. Previous studies have found that tannin-free faba beans have an increased incidence of seedling disease and emergence problems (Kantar et al., 1996). Seeds from tannin-free cultivars tend to have poor emergence, a higher incidence of testa and cotyledon cracking, a smaller percentage of hard seeds, more rapid water uptake and greater leaching of solutes, all of which can stimulate fungal growth around germinating seeds. Besides emergence and disease studies, there have been no

published agronomic studies (seeding date, seeding rate, desiccation) conducted specifically for tannin-free faba beans.

Modifications to the seeding date and seeding rate may help tannin-free faba beans to overcome these problems and achieve higher yields and quality. Late seeding into warmer soils may improve germination and higher seeding rates may compensate for seedling losses caused by disease. Kantar et al. (1994) indicated that tannin-free faba beans may develop to a critical stage where the entry of fungal pathogens is resisted. Rapid development to this critical stage is expected when seeding is delayed and soil temperatures are warmer.

The recommended seeding date for faba beans, in Canada, is from early to mid-May (Rowland, 1978). Park and Lopetinsky (1999) also recommend early seeding, and state that faba bean should be seeded by May 7, in Alberta. Early seeding is necessary to ensure adequate time for maturity, as the majority of faba bean varieties are indeterminate and therefore require a long growing season. Early seeding is particularly important in years with early fall frosts that can decrease yield and quality (Evans and Slinkard, 1975). However, early seeding can expose the crop to an increased risk of spring frost damage (Thompson and Taylor, 1977; Knott et al., 1994). Kantar et al. (1996) suggested that tannin-free faba beans would have reduced populations when seeded early.

The risk of aphid damage, drought stress, poor weed control with soil-acting herbicides, seed-bed drying out, late maturity, and late harvest all increase with delayed seeding (Hebblethwaite et al., 1977; Knott et al., 1994). Late seeding can

also coincide with high temperatures at the time of flower and pod set (Hebblethwaite et al., 1983). Temperatures exceeding 27°C at the time of flowering are associated with blossom drop and seed set failure (Kay, 1979). Late seeded faba beans may develop their maximum leaf area too late to make the most use of long days in late June and July (Hebblethwaite et al., 1983).

Seeding date strongly influences faba bean seed yield (Kondra, 1975; Rowland, 1978; Martiniello and Ciola, 1995). Marcellos and Constable (1986) found late seeding to result in shorter vegetative and pod filling stages which translated into smaller plants and reduced yields. Despite decreases in yield, seed protein levels were largely unaffected by seeding delays (Rowland, 1978; McVetty et al., 1986).

Studies in the UK have shown that increasing plant populations of spring seeded faba beans from 12 to 86 plants m^{-2} gave a diminishing positive yield response for both large seeded (680mg $seed^{-1}$) and small seeded (454mg $seed^{-1}$) faba beans (Ingram and Hebblethwaite, 1976). Large seeded faba beans reached a yield plateau at lower plant populations than the small seeded faba beans. Kondra (1975) examined the effects of seeding rate on yield in Alberta. He examined three seeding rates (100, 150, and 200 kg ha^{-1}) and found that a low seeding rate of 100 kg ha^{-1} had depressed yields. The 150 and 200 kg ha^{-1} seeding rates showed higher yields than the 100 kg ha^{-1} seeding rate, but were not significantly different from each other indicating a diminishing positive yield response.

In England, optimum yields of spring seeded faba bean are achieved with a final plant population of 40 plants m^{-2} (Knott et al., 1994). A seeding rate of 40 plants m^{-2} is also recommended in Alberta (Park and Lopetinsky, 1999). Studies conducted in England found that under fertile soil conditions, a slightly lower seeding rate may be acceptable, but for dry conditions a slightly higher seeding rate is recommended (Knott et al., 1994).

The main objective of this study was to determine the optimum seeding date and seeding rate required to achieve high yields and quality of large and small seeded, tannin-free, faba beans by measuring cultivar response to a range of seeding dates and seeding rates at two sites in north central Alberta.

2.2 Materials and Methods

2.2.1 Experimental Design

Experiments were seeded at Legal and Neerlandia, Alberta, in 2001 and 2002. Soil at Legal is a Black Solodized Solonetz developed on till parent material (Bowser et al., 1962) and soil at Neerlandia is a Gleyed Orthic Black Chernozem developed on till and alluvial-lacustrine parent material (Wynnyk et al., 1969).

The experiment was a split-split plot design, with four blocks. Seeding date formed the main plot, seeding rate the sub-plot and cultivar the sub-sub-plot. The three seeding dates were April 25, May 4, and May 14, 2001. These dates were selected as they surround the recommended seeding date of May 7th, suggested by

Park and Lopetinsky (1999). In 2002, seeding was delayed until May 8, May 17, and May 27, 2002 due to excessive moisture conditions and cold soil temperatures. The amount of seed planted was adjusted for germination results, to meet target seeding rates of 32, 43 and 65 plants m^{-2} (Appendix I, Table I-1, Plate 2-1). Seeding rates used in this study were selected to examine low, recommended (40 plants m^{-2} (Park and Lopetinsky, 1999)), and high seeding rates. The four cultivars tested were Cresta, a large seeded, tannin-free cultivar, CDC Blitz, a small seeded, indeterminate, tannin-containing cultivar, Snowbird, a medium seed sized, tannin-free cultivar, and Earlibird, a medium seed sized, determinate, tannin-containing cultivar. Samples of these were sent to 20/20 Seed Labs, Nisku for germination, vigor and emergence testing and electrical conductivity (EC) analysis (Appendix I, Table I-2). In 2001, results from these tests were not received until May 24, so seeding rate calculations were based on an estimated germination rate of 90% while actual germination rates ranged from 74–81% (Appendix I, Table I-1). In 2002, results were received prior to seeding and actual germination results were used to calculate seeding rates.

Each sub-sub-plot was 6.4 meters long and four rows wide, with 20 cm row spacing. Plots were seeded with a double-disc, press drill, plot seeder into wheat stubble. In 2001, due to dry soil conditions, the seeding depth was 7.6 cm to ensure that seed was placed into moist soil. In 2002, there were good soil moisture conditions, so seed was planted 5 cm deep. At the time of seeding, 1.4 g $plot^{-1}$ of MicroBio Rhizogen Self-Stick Legume Inoculant for Faba beans, was mixed with

the seed and placed in the furrow with the seed. The inoculant contained $1x10^9$ *Rhizobium leguminosarum* biovar *viceae* bacteria g^{-1}.

2.2.2 Soil Sampling

Six random soil samples were taken, at each location, and for each sampling date, at 0-15 cm and 15-30 cm and sent to Norwest Labs, Edmonton for analysis. Soil samples were collected in October 2001, in pathways between blocks, to estimate soil nutrients at the beginning of the 2001 growing season (Appendix I, Table I-3). In May 2002, soil samples were taken prior to seeding to determine initial soil nutrients (Appendix I, Table I-4). Results from the soil tests were not known at the time of seeding. Therefore, both sites in 2001 and 2002, were fertilized with 7 kg ha^{-1} N and 32 kg ha^{-1} P_2O_5. This was done based upon faba bean's high requirement for phosphorous. It is recommended that black soils with an average level (i.e. 55 kg ha^{-1}) of soil test P require the addition of 37 kg ha^{-1} P_2O_5 fertilizer (Norwest Labs, 2002). These application rates were within 5 to 8 kg ha^{-1} of the recommended rates for P_2O_5 at both locations in 2002 (Appendix I, Table I-4). Soil test results indicated that phosphorous should have been added at Legal in 2001 and potassium and sulfate should have been added at Legal in 2002 (Appendix I, Table I-3; Table I-4).

Following harvest in 2002, soil samples were taken in September and October at Legal and Neerlandia, respectively. Soil samples were collected using the same methodology as used in pre-seeding soil sampling. These samples were

used to measure nutrient removal or nutrient additions by the crop, over the 2002 growing season (Appendix I, Table I-5).

2.2.3 Environmental Data

Soil temperatures were taken (15cm) at each location, in each year, at the time of seeding (Appendix I, Table I-6). Precipitation data was taken at each location from the time of seeding until harvest with a rain gauge (Appendix I, Table I-7). Precipitation from the Legal site was compared with thirty year average precipitation data from the Environment Canada, Namao Meteorological Station, located 13 km from Legal. Precipitation data from Neerlandia was compared with thirty year average precipitation data for the AAFRD, North Western Alberta Agriculture Region (Appendix I, Table I-7). Yearly temperature data from the AAFRD North Western Alberta Agriculture Region will be compared to the 30 year average temperature data for the AAFRD North Western Alberta Agriculture Region (Appendix I, Table I-8) and this data was used for both locations.

Growing degree days were calculated for each site in each year, using a base temperature of 5°C (Appendix I, Table I-9). Growing degree days for Legal, in 2001 and 2002, was based on daily temperature data from the Edmonton Research Station (ERS) meteorological station, located 47 km from Legal. In 2001, growing degree days for Neerlandia were attained from the historical, accumulated totals for the Whitecourt/Barrhead/Swan Farmzone Region (Farmzone Historical Accumulated Totals, 2001). In November 2001, a drought monitoring

station was set up 32 km from Neerlandia. Daily temperature data from this station was used to calculate growing degree days for Neerlandia in 2002.

2.2.4 Weed Control and Plot Maintenance

In 2001, both locations were sprayed (Table 2.1) with a Poast Ultra and Pursuit tank mix at the recommended rate for field pea (Ali et al., 2001). Imazethapyr (Pursuit) at a rate of 17 mL ha^{-1} and 76 mL ha^{-1} of sethoxydim (Poast) were applied with a water volume of 112 L ha^{-1}. Subsequent hand weeding was done to control weed flushes. Neerlandia was desiccated with 0.4L ha^{-1} glyphosate (Roundup) and Legal was desiccated with 0.32 L ha^{-1} diquat (Reglone Pro) to assist with drydown (Table 2.1).

Odyssey was used, at both sites in 2002, to control weeds (Table 2.1). According to the recommendations for field pea, 6.8g ha^{-1} of imazamox + imazethapry (Odyssey) was applied with a water volume of 112 L ha^{-1} (Ali et al., 2001). Once again, hand weeding was necessary to control subsequent weed flushes. Both sites were desiccated with 0.32 L ha^{-1} diquat (Reglone Pro) to assist with drydown (Table 2.1). In both years the area between blocks was rototilled to control weeds and allow for plot access.

2.2.5 Plant Populations

Two plant population counts were conducted in 2001 (Appendix I, Table I-10). In 2002, three plant population counts were conducted due to a prolonged emergence period caused by extremely cool soil temperatures. In 2002, some cutworm damage was observed at the seedling stage therefore, a final plant

population count was done prior to harvest to determine if plant population losses occurred. Plant population counts began once seedlings had emerged and first leaves had unfolded. Subsequent counts were completed three to five days later. Seedlings were counted, at the center of each sub-sub plot, in two one-meter rows.

Final plant population data was based on the final spring counts which were taken approximately 3 weeks after seeding in 2001, and approximately 4 weeks after seeding in 2002.

2.2.6 Days to 10% Flower

Sub-sub plots were monitored to determine the progress of flowering. Monitoring began in late June (Table 2.1) continued until all sub-sub plots had reached 10% flower. Ten percent flower was achieved when ten percent of the plants within each sub-sub-plot had at least one open flower.

2.2.7 Chocolate Spot Assessments

Chocolate spot assessments were conducted (Table 2.1). Leaves of three randomly selected plants, per sub-sub plot, were assessed on a nine-point scale. The nine point scale used here (Appendix I, Table I-11, Plate I-1) was devised based on the symptoms of faba beans infected with chocolate spot as described in Knott et al. (1994).

2.2.8 Leaf Drop Assessment

Premature leaf drop occurred in 2001 therefore, leaf drop assessments were conducted (Table 2.1). Sub-sub plots were visually rated as having no, slight,

moderate, or severe leaf drop (Appendix I, Table I-12). Leaf drop was not observed in 2002.

2.2.9 Plant Height Measurements

Plant height measurements were taken when most plants had finished flowering (Table 2.1). Two height measurements were made per sub-sub plot with plants held vertical and measured to the tip of the tallest extended leaf.

2.2.10 Lodging Assessment

Lodging occurred at Neerlandia in 2001 therefore, an assessment was conducted (Table 2.1). A visual evaluation was used to determine the percentage of the sub-sub plot that contained lodged faba bean plants.

2.2.11 Physiological Stage at Harvest

The physiological stage, at the time of harvest, was assessed to determine the treatment effects on maturity (Table 2.1). In 2001, the physiological stage was assessed as the percent black stems existing in the sub-sub-plot. In 2002, the physiological stage was assessed as the percent black pods existing in the sub-sub plot. Percent black pods were used as an indicator of maturity in 2002 because differences in percent black pods were easier to observe. At Legal in 2002, some plots suffered from *Fusarium* sp. and *Verticillium* sp. infection which turned stems black prematurely, by using percent black pods as a maturity indicator in 2002, confusion between disease and physiological stage were avoided.

2.2.12 Seed Yield

Individual sub-sub plots were harvested using a Wintersteiger plot combine (Table 2.1). Harvested seed was dried for 24 - 48 hours at 30 - 33°C in a forced air drier. Dried samples were weighed and 1000 kernel weight was determined.

In 2002, seed shattering occurred. In order to estimate these losses, a piece of legal sized paper (0.08 m^2) was placed over the middle two rows, at the center of the harvested sub-sub plot. Seeds lying within this area were counted. To determine the lost yield, the number of seeds lost per sub-sub plot was multiplied by the sub-sub plot's 1000 kwt and this value was added to the sub-sub plot's yield.

2.2.13 Protein Analysis

A 20g seed sub-sample was obtained from the harvested seed for blocks two and four at Neerlandia in 2001 and 2002. This sub-sample was ground into a homogeneous mixture using a Braun KSM2 Type 4041 coffee grinder and organic nitrogen content was determined for two to three 100 mg sub-sub samples using a Leco FP-428 Nitrogen Determinator (Leco® Corporation, St. Joseph, MI, USA). Percent crude protein was determined by multiplying the organic nitrogen content by 6.25 (Krogman et al., 1980).

2.2.14 Statistical Analysis

Data were analyzed using analysis of variance. Statistical analysis was completed using Statistical Analysis System (SAS Institute, 1999). Linearity and deviations from linearity were tested on the seeding date and seeding rate data using orthogonal contrasts. Orthogonal contrast coefficients used for the seeding rate data were adjusted to compensate for the unbalanced seeding rates uses in this

study. A Duncan's multiple range test was used to separate the means when there were significant differences between cultivars ($P<0.05$). Chocolate spot, leaf drop and lodging data were transformed with a square root transformation to adjust for their heterogeneous variance or deal with the nature of the count data.

2.3 Results

2.3.1 Environmental Data

In 2001, Legal received near average precipitation for the growing season, in comparison to the Environment Canada, Namao Meteorological Station 30 year average (Appendix I, Table I-7). The months of May, June, and September had below average precipitation, while July and August had above average precipitation. Neerlandia, in 2001, received less precipitation than Legal. Precipitation at Neerlandia was 103 mm less than the 30 year average for the AAFRD North Western Alberta Agriculture Region. Extremely wet conditions occurred at both sites towards the end of July, 2001. In the last week of July both sites received approximately 55% of their total seasonal precipitation. This created some flooding and water logging at the Legal site due to poor drainage. Neerlandia had good drainage which prevented water logged conditions from developing. In 2002, both locations suffered drought conditions, with total precipitation at Legal being 26% of the Environment Canada, Namao Meteorological Station 30 year average and total precipitation at Neerlandia being 51% of the AAFRD North Western Alberta Agriculture Region 30 year average.

In 2001, temperatures for the AAFRD North Western Alberta Agriculture Region above the 30 year average occurred in May, August, and September resulting in a warm spring and fall (Appendix I, Table I-8). Near average temperatures occurred in June and July. The 2002 growing season began with spring temperatures below the AAFRD North Western Alberta Agriculture Region 30 year average, followed by above average temperatures in June and July. Below average temperatures occurred in the fall of 2002. Warmer temperatures in June and July 2002, resulted in greater growing degree days in 2002 compared to 2001. The first killing frost occurred October 5th in 2001 and September 7th in 2002.

Soil temperatures (15cm depth) at the time of seeding were cooler at Neerlandia compared to Legal, in 2001 and 2002 (Appendix I, Table I-6). In 2001, dry soil conditions existed at the time of seeding and soil temperatures ranged from 11.5°C to 15.2°C (15cm depth). In 2002, soils were extremely wet and much cooler with temperatures ranging from - 4.0°C to 11.0°C (15cm depth).

2.3.2 Soil Nitrogen

Nitrate-N increased in the post-harvest 0 to 15cm soil samples compared to the pre seeding soil samples, at both locations in 2002 (Appendix I, Table I-5). Electrical conductivity increased and pH decreased in the post harvest 0 to 15 cm soil samples compared to the pre seeding soil samples, at both locations.

2.3.3 Year and Location

Plant height ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), chocolate spot infection ($P \leq 0.01$), and crude protein content ($P \leq 0.05$) differed between years

(Table 2.2). Year did not significantly affect yield, rate of yield gain per day, or plant population ($P \geq 0.05$) (Table 2.2).

Plants were taller (72 cm verses 56 cm), days to 10% flower were longer (51 days verses 45 days) and chocolate spot infection was higher (4.7 verses 1.8) in 2001 than in 2002 (data not included). Protein levels were higher in 2002 (27.2%) than in 2001 (26.4%) (data not included).

Location significantly affected yield ($P \leq 0.01$), rate of yield gain per day ($P \leq 0.01$), plant population ($P \leq 0.01$), plant height ($P \leq 0.01$), leaf drop ($P \leq 0.01$), and physiological stage at maturity ($P \leq 0.01$, 2001; $P \leq 0.01$, 2002) (Table 2.2). Location did not significantly affect days to 10% flower or chocolate spot infection ($P \geq 0.05$).

Yields were higher (5.2 t ha^{-1} verses 1.9 t ha^{-1}), rate of yield gain per day was higher (59 kg ha^{-1} day^{-1} versus 22 kg ha^{-1} day^{-1}), plant populations were higher (43 plants m^{-2} verses 35 plants m^{-2}), and plants were taller (84 cm verses 45 cm) at Neerlandia than at Legal (data not included). There was more leaf drop in Legal (1.40) than in Neerlandia (0.52) (data not included).

There was a significant year x location interaction for yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), days to 10% flower ($P \leq 0.05$), and chocolate spot infection ($P \leq 0.05$) (Table 2.2). At Neerlandia, significantly higher yields occurred in 2002 (5.6 t ha^{-1}) compared to 2001 (4.8 t ha^{-1}) (data not included). This trend was reversed for Legal, where 2001 yields (2.4 t ha^{-1}) were significantly higher than 2002 yields (1.4 t ha^{-1}) (data not included). The significant interactions for days to 10% flower and chocolate spot infection were caused by magnitude differences.

Due to the significant year x location interactions and differences between years and locations, all results are presented for each site year.

2.3.4 Legal 2001

At Legal in 2001 seeding date did not affect yield, yield gain per day, plant population, or chocolate spot ($P \geq 0.05$) (Table 2.3). Seeding date significantly affected height ($P \leq 0.01$), leaf drop ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$).

Height increased (linear $P \leq 0.05$; deviation $P \leq 0.01$) as seeding was delayed (Table 2.4). Leaf drop and days to 10% flower decreased (linear $P \leq 0.01$; deviation $P \leq 0.01$) as seeding was delayed. Physiological stage at harvest became less advanced as seeding was delayed (deviation $P \leq 0.01$).

Seeding rate had no significant effect on most measured traits, the exceptions being plant population ($P \leq 0.01$), leaf drop ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$) (Table 2.3).

Plant populations increased (linear $P \leq 0.01$; deviation $P \leq 0.05$) as seeding rate increased (Table 2.4). Leaf drop showed a significant linear trend ($P \leq 0.01$) with leaf drop increasing as seeding rate increased. Physiological stage at harvest became more advanced as seeding rate increased from 32 plants m^{-2} to 43 plants m^{-2} (deviation $P \leq 0.01$).

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (Table 2.3). Blitz (2.9 t ha^{-1}) and Snowbird (2.7 t ha-1) had the highest yields while Blitz had the greatest rate of yield gain per day (34 kg ha^{-1} day^{-1}) (Table 2.4). Earlibird had

the lowest yields (1.8 t ha^{-1}) and lowest rate of yield gain per day (19 kg ha^{-1} day^{-1}). Blitz had the highest plant populations (40 plants m^{-2}) compared to the other three cultivars. Cresta and Earlibird were the first to flower (47 days) while Blitz was the last to flower (56 days). Earlibird (5.2) had significantly higher levels of chocolate spot infection compared to other cultivars. Earlibird (2.0) and Snowbird (1.8) had significantly more leaf drop compared to Blitz (0.9) and Cresta (0.9). Blitz was the tallest cultivar (64 cm) while Earlibird was the shortest (48 cm). Earlibird was at the most advanced physiological stage at the time of harvest while Blitz and Cresta were the least advanced.

The seeding date x seeding rate interaction was not significant for most measured traits the exception being plant population ($P \leq 0.01$) and physiological stage at harvest ($P \leq 0.01$) (Table 2.3).

Plant population increased with increasing seeding rate at all seeding dates, however, the early seeding date increased more rapidly from 32 to 43 plants m^{-2} (Figure 2.1). Physiological stage at harvest became more advanced as seeding rate increased from 32 to 43 plants m^{-2}, however, the increase in physiological stage was greater for the early seeding date than at the mid or late seeding dates (Figure 2.2).

The seeding date x cultivar interaction was not significant for yield, plant population, or leaf drop ($P \geq 0.05$) (Table 2.3). There was a significant seeding date x cultivar interaction for yield gain per day ($P \leq 0.05$), plant height ($P \leq 0.01$), days to

10% flower ($P \leq 0.01$), chocolate spot infection ($P \leq 0.05$), and physiological stage at harvest ($P \leq 0.01$).

The yield gain per day, seeding date x cultivar, interaction showed that Earlibird, Snowbird, and Cresta had increasing rates of yield gain as seeding was delayed (Figure 2.3). However, Blitz had an increasing rate of yield gain from the early to the mid seeding date but yield gain decreased slightly at the late seeding date.

The plant height, seeding date x cultivar, interaction showed all cultivars increasing in plant height as seeding was delayed, with Blitz exhibiting the strongest response (Figure 2.4).

The days to 10% flower, seeding date x cultivar, interaction showed that Blitz had a steady decrease in days to 10% flower as seeding was delayed. Cresta and Earlibird also had a decrease in days to 10% flower as seeding was delayed, but days to 10% flower were similar for the mid and late seeding dates (Figure 2.5).

Chocolate spot, seeding date x cultivar, interaction showed decreasing infection as seeding was delayed for Snowbird, Blitz, and Cresta (Figure 2.6). The level of chocolate spot infection was constant for the cultivar Earlibird regardless of seeding date.

The physiological stage at harvest seeding date x cultivar interaction showed decreases in % black stems as seeding was delayed for Earlibird, Snowbird, and Cresta. Seeding date did not affect the physiological stage of the cultivar Blitz between the mid and late seeding dates (Figure 2.7).

The seeding rate x cultivar and seeding date x seeding rate x cultivar interactions were not significant for any measured traits at Legal in 2001 ($P \geq 0.05$) (Table 2.3).

2.3.5 Neerlandia 2001

At Neerlandia in 2001, seeding date significantly affected all measured characteristics: yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$) plant population ($P \leq 0.05$), height ($P \leq 0.01$), leaf drop ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), chocolate spot infection ($P \leq 0.01$), lodging ($P \leq 0.01$), physiological stage at harvest ($P \leq 0.01$), and crude protein content ($P \leq 0.05$) (Table 2.3).

Yield and height increased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.05$) (Table 2.5). Yield gain per day and lodging increased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$). Plant population was lowest at the mid seeding date (linear $P \leq 0.05$). Leaf drop decreased as seeding was delayed (linear $P \leq 0.05$; deviation $P \leq 0.01$). Days to 10% flower and physiological stage at harvest lessened as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$). Crude protein content showed a significant deviation from a linear trend ($P \leq 0.05$) with crude protein content decreasing as seeding was delayed.

Seeding rate had no significant effect on most measured traits ($P \geq 0.05$), the exception being plant population ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$) (Table 2.3).

Plant population followed a significant linear trend ($P \leq 0.01$) with plant population increasing as seeding rate increased (Table 2.5). Physiological stage at

harvest was least advanced at the mid seeding rate (linear $P \leq 0.01$; deviation $P \leq 0.01$).

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (Table 2.3). Snowbird had the highest yields (5.5 t ha^{-1}) and the greatest rate of yield gain per day (67 kg ha^{-1} day^{-1}) while Earlibird had the lowest yields (4.1 t ha^{-1}) and lowest rate of yield gain per day (47 kg ha^{-1} day^{-1}) (Table 2.5). Blitz had the highest plant populations (48 plants m^{-2}) while Cresta had the lowest plant populations (38 plants m^{-2}). Cresta and Earlibird were the first to flower (47 days) while Blitz was the last to flower (56 days). Earlibird had significantly more chocolate spot infection (5.4) compared to other cultivars. Earlibird (1.6) had the highest amounts of leaf drop while Blitz (0.0) and Cresta (0.1) had virtually none. Blitz was the tallest (107 cm) and Earlibird was the shortest cultivar (81 cm). Earlibird and Snowbird had minimal lodging but 64% of the Blitz and 45% of the Cresta sub-sub plots were lodged. Blitz was at the least advanced physiological stage at the time of harvest while Snowbird was the most advanced. Cresta (28.4%) had the highest crude protein content, while Earlibird (24.9%) had the lowest.

The seeding date x seeding rate interaction was not significant for most measured traits ($P \geq 0.05$), the exception being physiological stage at harvest ($P \leq 0.01$) (Table 2.3). Physiological stage at harvest, for plants seeded at the late seeding date, was less advanced at 43 plants m^{-2} compared to the other seeding rates (Figure 2.8)

There was a significant seeding date x cultivar interaction for yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), plant population ($P \leq 0.01$), height ($P \leq 0.01$), leaf drop ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), chocolate spot infection ($P \leq 0.01$), lodging ($P \leq 0.01$), physiological stage at harvest ($P \leq 0.01$), and crude protein content ($P \leq 0.05$) (Table 2.3).

The yield (Figure 2.9) and yield gain per day (Figure 2.10) seeding date x cultivar interactions, resulted from differences in cultivar response at the mid and late seeding dates. Earlibird, Snowbird, and Cresta had maximum yields and rates of yield gain at the late seeding dates. Blitz had maximum yields and rates of yield gain at the mid seeding date.

Plant population, seeding date x cultivar, interaction reflected Earlibird and Cresta maximizing plant populations at the late seeding date while Snowbird and Blitz maximized their plant populations at the early seeding date (Figure 2.11).

Height, leaf drop, and lodging, seeding date x cultivar interactions, resulted from magnitude differences of the cultivars at the different seeding dates. The height response was greatest in Blitz and least in Earlibird (Figure 2.12). Leaf drop occurred for Earlibird, Snowbird, and Cresta at the early seeding date but only Earlibird had leaf drop at the mid and late seeding dates (Figure 2.13). Maximum lodging was seen at the late seeding date for all cultivars, while only Blitz and Cresta experienced lodging at the early seeding date (Figure 2.14).

Days to 10% flower, seeding date x cultivar, interaction resulted from days to 10% flower being relatively consistent for Cresta and Earlibird between the mid and late seeding dates while it declined for Snowbird and Blitz (Figure 2.15).

Chocolate spot, seeding date x cultivar, interaction showed chocolate spot infection decreasing as seeding was delayed for Snowbird, Blitz, and Cresta (Figure 2.16). However, the level of chocolate spot infection was constant for Earlibird regardless of seeding date.

The crude protein content, seeding date x cultivar, interaction showed Snowbird and Earlibird with highest crude protein contents at the mid seeding date (Figure 2.17). For Blitz and Cresta, crude protein content decreased as seeding was delayed.

The physiological stage at harvest, seeding date x cultivar, interaction showed physiological stage at harvest was less advanced as seeding was delayed (Figure 2.18). Earlibird and Snowbird showed the greatest response while Blitz showed the least.

The seeding rate x cultivar interaction and seeding date x seeding rate x cultivar interactions were not significant for most measured traits ($P \geq 0.05$), the exception being physiological stage at harvest ($P \leq 0.01$) (Table 2.3).

2.3.6 Legal 2002

At Legal in 2002, seeding date had a significant effect on yield ($P \leq 0.05$), yield gain per day ($P \leq 0.05$), height ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), and the

physiological stage at maturity ($P \leq 0.01$). Seeding date did not significantly affect plant population or chocolate spot infection ($P \geq 0.05$) (Table 2.6).

Yield and yield gain per day showed a significant linear trend (yield $P \leq 0.05$; yield gain per day $P \leq 0.01$) with maximum yields and yield gains at the mid seeding date (Table 2.7). Plant height increased as seeding was delayed (linear $P \leq 0.05$; deviation $P \leq 0.01$). Days to 10% flower and physiological stage at maturity lessened as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$).

Seeding rate had a significant effect on yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), plant population ($P \leq 0.01$), height ($P \leq 0.01$), and chocolate spot infection ($P \leq 0.01$) (Table 2.6). Seeding rate did not significantly affect the days to 10% flower or physiological stage at harvest ($P \geq 0.05$).

Yield, yield gain per day, and plant population all followed a significant linear trend ($P \leq 0.01$) and all increased as seeding rate increased (Table 2.7). Height and chocolate spot infection followed a significant linear trend ($P \leq 0.01$) and both declined as seeding rate was increased.

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (Table 2.6). Blitz and Earlibird had the highest yields (1.6 t ha^{-1}) while Cresta (1.3 t ha^{-1}) and Snowbird (1.2 t ha^{-1}) had the lowest yields (Table 2.7). Blitz had the highest rate of yield gain (20 kg ha^{-1} day^{-1}). Blitz (38 plants m^{-2}) and Earlibird (42 plants m^{-2}) had the highest plant populations while Cresta (33 plants m^{-2}) and Snowbird (31 plants m^{-2}) had the lowest plant populations. Earlibird (41 days) was the first to flower while Blitz was the last to flower (49 days). Earlibird had significantly lower levels

of chocolate spot infection (1.4) compared to the other cultivars. Blitz was tallest (41 cm) and Earlibird was shortest (29 cm). Blitz was at the least advanced physiological stage and Earlibird was at the most advanced physiological stage at the time of harvest.

The seeding date x seeding rate interaction was not significant for most measured traits, the exception being yield ($P \leq 0.05$), and days to 10% flower ($P \leq 0.01$) (Table 2.6).

The yield interaction resulted from a yield decrease between the 43 and 65 plants per m^{-2} seeding rates, for the mid seeding date, while yield increased at the early and late seeding dates (Figure 2.19). The days to 10% flower interaction resulted from the days to 10% flower decreasing for the late seeding date but increasing for the early and mid seeding dates (Figure 2.20).

The seeding date x cultivar interaction was not significant for plant population, height, or chocolate spot infection ($P \geq 0.05$) (Table 2.6). There was a significant seeding date x cultivar interaction for yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$).

Yield (Figure 2.21) and yield gain per day (Figure 2.22) seeding date x cultivar interactions showed Earlibird, Snowbird, and Cresta having maximum yields and yield gains per day at the mid and late seeding dates. Blitz had maximum yields and yield gains per day at the early and mid seeding dates.

The days to 10% flower, seeding date x cultivar, interaction can be explained by Earlibird and Cresta exhibiting a greater magnitude of response than Snowbird and Blitz (Figure 2.23).

The physiological stage at harvest, seeding date x cultivar, interaction showed decreases in percent black pods as seeding was delayed for Earlibird, Snowbird, and Cresta. Blitz had no black pods when seeded at the late seeding date (Figure 2.24).

The seeding rate x cultivar interaction was significant for yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$) (Table 2.6). There was no significant seeding rate x cultivar interaction for any other measured parameter ($P \geq 0.05$).

Yield, seeding rate x cultivar, interaction showed that yields were constant regardless of seeding rate for Blitz while Earlibird, Cresta, and Snowbird had maximum yields at the high seeding rate (Figure 2.25).

The physiological stage at harvest, seeding rate x cultivar, interaction showed that the least advanced physiological stage was at the 43 plants m^{-2} seeding rate for Snowbird but at this seeding rate Cresta had the most advanced physiological stage (Figure 2.26).

The seeding date x seeding rate x cultivar interaction was not significant for most measured traits ($P \geq 0.05$), the exception being yield gain per day ($P \leq 0.05$) (Table 2.6).

2.3.7 Neerlandia 2002

At Neerlandia in 2002, seeding date did not significantly affect yield, yield gain per day, plant population, chocolate spot infection, or crude protein content ($P \geq 0.05$). Seeding date significantly affected height ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), and physiological stage at harvest ($P \leq 0.01$) (Table 2.6).

Height increased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$) (Table 2.8). Days to 10% flower decreased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$). Physiological stage at harvest was less advanced when seeding was delayed (deviation $P \leq 0.01$).

Seeding rate had a significant effect on yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), plant population ($P \leq 0.01$), height ($P \leq 0.01$), chocolate spot infection ($P \leq 0.05$), and physiological stage at harvest ($P \leq 0.01$) (Table 2.6). Seeding rate did not significantly affect days to 10% flower, or crude protein content ($P \geq 0.05$).

Yield, yield gain per day, and plant population all showed a significant linear trend ($P \leq 0.01$) and all increased as seeding rate increased (Table 2.8). Height showed a significant linear trend ($P \leq 0.01$) with height decreasing as seeding rate increased. Chocolate spot infection showed a significant linear trend ($P \leq 0.05$) with infection levels increasing as seeding rate increased. Physiological stage at harvest became more advanced as seeding rate increased (linear $P \leq 0.01$; deviation $P \leq 0.05$).

Chocolate spot infection was not significantly different between cultivars ($P \geq 0.05$) but cultivars differed for all other measured traits ($P \leq 0.01$) (Table 2.6). Snowbird had the highest yield (6.1 t ha^{-1}) and yield gain per day (70 kg ha^{-1} day^{-1})

while Earlibird had the lowest yield (5.1 t ha^{-1}) and lowest gain per day (53 kg ha^{-1} day^{-1}) (Table 2.8). Blitz (47 plants m^{-2}) and Earlibird (45 plants m^{-2}) had the highest plant populations while Cresta (36 plants m^{-2}) and Snowbird (40 plants m^{-2}) had the lowest plant populations. Earlibird (40 days) was the first to flower while Blitz was the last to flower (50 days). Blitz was the tallest cultivar (93 cm) and Earlibird was the shortest (63 cm). Cresta was at the least advanced physiological stage while Earlibird and Snowbird were the most advanced physiological stage at the time of harvest.

The seeding date x seeding rate interaction was not significant for most measured traits ($P \geq 0.05$), the exception being height ($P \leq 0.05$) and physiological stage at harvest ($P \leq 0.01$) (Table 2.6).

The height, seeding date x seeding rate, interaction shows plant height decreasing for the 65 plant m^{-2} seeding rate at the mid seeding date while it was relatively constant otherwise (Figure 2.27).

The physiological stage at harvest, seeding date x seeding rate, interaction showed that the mid and late seeding dates had a more advanced physiological stage as seeding rate increased, but the early seeding date decreased slightly as seeding rate increased (Figure 2.28).

The seeding date x cultivar interaction was significant for yield ($P \leq 0.01$), yield gain per day ($P \leq 0.01$), height ($P \leq 0.01$), days to 10% flower ($P \leq 0.01$), physiological stage at harvest ($P \leq 0.01$), and crude protein content ($P \leq 0.01$) (Table

2.6). There was no significant seeding date x cultivar interaction for plant population or chocolate spot infection ($P \geq 0.05$).

The yield (Figure 2.29) and yield gain per day (Figure 2.30), seeding date x cultivar, interactions reflect yield and yield gain being maximized at a different seeding date for each cultivar. Snowbird and Blitz had maximum yields and gains at the early seeding date. Earlibird had maximum yields and gains at the late seeding date and Cresta had maximum yields at the mid seeding date.

The height (Figure 2.31) and days to 10% flower (Figure 2.32) seeding date x cultivar interactions showed magnitude differences between the cultivars. For height, Blitz and Snowbird had a more linear response than Earlibird and Cresta. For days to 10% flower, Earlibird and Cresta exhibited a response of greater magnitude than Blitz and Snowbird.

The crude protein content, seeding date x cultivar, interaction showed that Earlibird and Cresta had decreasing crude protein contents as seeding was delayed (Figure 2.33). Snowbird had relatively constant protein content regardless of seeding date. Blitz had its lowest crude protein content at the mid seeding date.

The physiological stage at harvest, seeding date x cultivar, interaction showed physiological stage at harvest being less advanced as seeding was delayed (Figure 2.34). Blitz showed the greatest response while Earlibird showed the least.

The seeding rate x cultivar, and seeding date x seeding rate x cultivar interactions were not significant for the measured traits ($P \geq 0.05$) (Table 2.6).

2.4 Discussion

One challenge associated with seeding date studies conducted over multiple growing seasons is the problem of differing environmental conditions (Plates 2-2, 2-3). In our study, spring seeding conditions were extremely different in the two years of the study. Due to excessive soil moisture and extremely cold soil temperatures, seeding in the second year (2002) of the study was delayed by 13 days. As a result, actual seeding dates were later in 2002 than in 2001, however due to above average temperatures in 2002 there were approximately 200 more GDD's at Legal in 2002 than in 2001 and approximately 100 more GDD's at Neerlandia in 2002 than in 2001. Above average temperatures in 2002 accelerated plant growth and resulted in similar maturities and harvest dates in the two years of the study. Despite differences in actual seeding date, the early (April 25, 2001 and May 8, 2002), mid (May 4, 2001 and May 17, 2002), and late (May 14, 2001 and May 27, 2002) seeding dates will be considered similar in both years of the study and will be referred to as such in the discussion.

2.4.1 Yield and Rate of Yield Gain

Previous research suggests that tannin-free faba bean seeds tend to have poor emergence, increased seedling disease, a higher incidence of testa and cotyledon cracking, a smaller percentage of hard seeds, more rapid water uptake and greater leaching of solutes compared to tannin-containing cultivars, and all of these can stimulate fungal growth around germinating seeds (Kantar et al., 1996). Based on this, tannin-free faba beans were expected to yield less than tannin-

containing faba beans especially when soil conditions, at the time of seeding, were wet and cool. It was hypothesized that tannin-free faba beans may need to be seeded later, once soil temperatures had increased. Kantar et al. (1994) indicated that tannin-free faba beans may develop to a critical stage where the entry of fungal pathogens is resisted. Rapid development to this critical stage was expected when seeding was delayed and soil temperatures were warmer. It was also hypothesized that higher seeding rates, for tannin-free cultivars, might be necessary to compensate for some seedling losses caused by disease.

In general, yield and rate of yield gain per day responded to all treatments in a similar manner. As a result, the discussion will focus on the yield responses. The magnitude of the yields in this study (1.2 to 5.8 t ha^{-1}) are similar to the yields obtained by Kondra (1975) for faba beans grown in central Alberta (2.5 to 6.3 t ha^{-1}), when seeding dates ranged from May 2 to May 30th.

In this study, yield did not decrease as seeding was delayed, in contrast to the findings of numerous other authors (Rowland, 1978; Park and Lopetinsky, 1999; Kondra, 1975; Martiniello and Ciola, 1995; McVetty et al., 1986; Baldwin, 1980; Marcellos and Constable, 1986). Early seeding reduced yields by 0.7t ha^{-1} at Neerlandia in 2001 and by 0.5 t ha^{-1} at Legal in 2002, compared to the mid seeding date, whereas yield was not affected by seeding date in the other site years. The higher yields at the mid seeding date, at Legal in 2002, a drought year, may have been due to plants at the mid seeding date receiving rainfall at critical physiological stages, although data was not collected to support this theory. Differences between

this study and previous studies may be partially due to the indeterminate nature of the cultivars used in all other previous studies or the longer growing season in the study by Thompson and Taylor (1977). Based on these findings, the recommended seeding date for tannin-containing and tannin-free faba beans in Alberta should be extended beyond the May 7th recommendation suggested by Park and Lopetinsky (1999).

Pilbeam and Hebblethwaite (1990) found that seed yields for a given variety were constant over a wide range of planting densities suggesting that optimum plant densities could be low. Yield was not affected by seeding rate in 2001, under average growing conditions despite that fact that target plant populations were not achieved. The findings of this study suggest that under average growing conditions, lower seeding rates (32 plants m^{-2}) are sufficient to achieve high yields, under north central Alberta growing conditions.

Seeding rate significantly affected yields in 2002, when drought conditions existed. Yield increased with increasing seeding rates indicating that higher seeding rates were required to achieve maximum yields under drought conditions, when individual plant size was small. Knott et al. (1994) recommended that slightly higher plant populations be used on drought prone soils.

Loomis (1983) found that in most crops, low planting densities make better use of soil water by avoiding early depletion. Martin et al. (1994) investigated this in field pea and found that higher planting densities depleted soil water earlier in the growing season but this did not decrease yields unless seeding rates were

greater than 200 plants m^{-2} when excessive intraspecific competition occurs (recommended field pea seeding rates range from 70 to 150 plants m^{-2}). The seeding rates used in this study (32, 43, and 65 plants m^{-2}) are generally below the range in which peak faba bean yields are achieved (60 plants m^{-2}) (Baldwin, 1980; Thompson and Taylor, 1977). It would appear that the seeding rates used in this test were low enough that even at the high seeding rate, intraspecific competition did not decrease yields under moisture stress conditions.

Cultivar differed for yield in all site years. Snowbird was one of the best yielding cultivars when environmental growing conditions were good. However, under extremely stressful growing conditions, such as those seen at Legal in 2002, this cultivar performed poorly. Earlibird, performed poorly, compared to the other cultivars, under average growing conditions (Legal 2001, Neerlandia 2001, Neerlandia 2002) presumably because its determinate growth habit prevented it from making full use of all available resources. Pilbeam and Hebblethwaite (1990) found that determinate cultivars did not make full use of their environmental resources, particularly light, at low plant densities. Under drought conditions, Earlibird performed well because its determinate growth habit limited the total sink size and enabled the established seeds to mature.

There was a significant seeding date x cultivar interaction affecting yield in three site years (Figure 2.9, Neerlandia 2001; Figure 2.21, Legal 2002; Figure 2.29, Neerlandia 2002). Earlibird and Cresta had their highest yields at the mid and late seeding dates while Blitz had its highest yields at the early and mid seeding dates.

Blitz is an indeterminate cultivar and was better able to utilize the longer growing periods following the early seeding date. Earlibird and Cresta are more determinate cultivars, compared to Blitz, and they were able to achieve optimum yields in a shorter growing season.

The significant seeding rate x cultivar interaction affected yields at Legal in 2002 (Figure 2.25). When extreme drought conditions occurred throughout the growing season, Earlibird, Cresta, and Snowbird all required a higher seeding rate to achieve optimal yields. Under drought conditions, each plant was small and therefore a large number of plants were needed to increase yield.

On average, tannin-free cultivars, Snowbird and Cresta yielded better than tannin-containing cultivars, Blitz and Earlibird. Delayed seeding, to avoid cool wet soil conditions, did not increase yield of tannin-free cultivars in this study. Nor was it necessary to use higher seeding rates to maximize yield of tannin-free cultivars. Based on this it does not appear that tannin-free cultivars require a modified agronomic production system to maximize yield.

2.4.2 Plant populations

Tannin-free faba beans were expected to have reduced plant populations when seeded early (Kantar et al., 1996). Delayed seeding and increased seeding rates were expected to increase plant populations for the tannin-free cultivars.

Seeding date had a significant effect on plant population at Neerlandia 2001, with lower plant populations at the mid seeding date. Seeding date did not influence plant populations in the three other site years. Delayed seeding did not

appear to be necessary for the successful establishment of tannin-free faba beans, as was initially hypothesized.

As expected, seeding rate significantly affected plant populations in all site years, with plant populations increasing from 30 to 50 plants m^{-2} (average of all locations) as seeding rate increased, from 32 to 65 plants m^{-2}. However, target plant populations were not achieved in either year. Hegarty (1977) found that percent germination (which was used to calculate seeding rates in this study) was a poor indicator of faba bean emergence in the field. He suggested that a leachate conductivity test is a better indicator of emergence in the field. Laboratory germination estimates should therefore, only be used as a guideline for determining seeding rates and seed stocks with high conductivity should not be used for sowing.

In 2001, when soil conditions were dry and warm at the time of seeding, Blitz had the highest plant populations and Cresta had the lowest plant populations. These differences may have been due to differences in seed size as larger seeds require more moisture to germinate (Forbes and Watson, 1994). Blitz is a small seeded cultivar and required less moisture to germinate compared to the large seeded cultivar, Cresta. The cultivars Snowbird and Earlibird had similar plant populations, despite differences in tannin content. Thus, under warm, dry soil conditions, seed size was the primary factor determining plant population establishment and not tannin content.

In 2002, when soil conditions were wet and cool at the time of seeding, Earlibird and Blitz (tannin-containing) had higher plant populations compared to

Snowbird and Cresta (tannin-free). Tannins in the seed coat of Earlibird and Blitz are presumed to act as a naturally occurring fungicide (Bond and Smith, 1989). It is possible that the two tannin-free cultivars were not able to avoid pathogen infection when the high soil moisture contents enhanced the pathogenicity of *Pythium* spp. (Pieczarka and Abawi, 1978). However, pathogen infection of the seeds was not measured, so there is no direct evidence to link lower plant populations of tannin-free cultivars with pathogen infection. The results from this experiment support the hypothesis that higher seeding rates may be necessary for tannin-free cultivars when soil conditions are cool and wet at the time of seeding. However, Snowbird yields were not decreased at Neerlandia in 2002 when low plant populations existed. This indicates that increased plant populations and therefore increased seeding rates may not be necessary for Snowbird to achieve high yields.

2.4.3 Days to 10% Flower

Flower initiation in faba bean is a long day response (Evans, 1959). In 2001, the number of days from seeding to 10% flower was delayed compared to 2002. This can be explained by the fact that in 2002, the experiment began May 8th when photoperiods were longer, compared to in 2001 when the experiment began April 25th.

There was a decrease in days to 10% flower as seeding was delayed, in all site years. The decrease in days to 10% flower was probably caused by the increase in photoperiod associated with later seeding dates (Evans, 1959).

Increasing seeding rates from 32 to 65 plants m^{-2} did not influence days to 10% flower. This is in contrast to Bochniarz et al. (1986) who found that as faba bean plant density increased from 30 to 70 plants m^{-2}, flowering was slightly delayed.

Days to 10% flower differed for each cultivar, in all site years. Earlibird and Cresta had fewer days to 10% flower while Blitz needed more days to reach 10% flower. Based on these findings, there is no connection between seed tannin content and days to 10% flower.

2.4.4 Chocolate Spot Infection

Chocolate spot infection varied between site years. The highest infection rates were recorded at Neerlandia in 2001 where relative humidity was high, due to a dense crop canopy which produced ideal conditions for disease development (Jellis et al., 1998). However, chocolate spot infection at this site was not severe enough to reduce yields, as Neerlandia in 2001 had higher yields than Legal in 2001.

At Neerlandia in 2001, chocolate spot infection was highest at the early seeding date and infection declined as seeding was delayed. Jellis et al. (1998) indicated that early seeding of faba beans should be avoided to reduce instances of chocolate spot because faba beans that suffer frost damage are more susceptible to the disease. However, there were no spring frosts in 2001.

Increasing seeding rate did not increase chocolate spot infection. At Legal in 2002, chocolate spot infection decreased as seeding rates were increased. At

Neerlandia in 2002, chocolate spot infection increased as seeding rates increased. However, differences were small and considered to be of little significance.

Earlibird had the highest levels of chocolate spot infection in 2001, when environmental conditions were conductive for disease development. This suggests that Earlibird has less genetic resistance to the disease compared to the other cultivars. The high levels of chocolate spot may have contributed to the reduced yields for Earlibird in 2001. At Legal in 2002, when drought conditions existed, Earlibird had the lowest infection levels.

The significant seeding date x cultivar interaction in 2001 gives further evidence to support the genetic susceptibility of the cultivar Earlibird to chocolate spot infection. Snowbird, Blitz, and Cresta had decreasing levels of chocolate spot infection as seeding was delayed whereas infection levels of Earlibird were high and similar at all seeding dates. This suggests that Earlibird is extremely susceptible to the disease even when other cultivars are showing some level of resistance. The cultivar description for Earlibird indicates disease resistance was a selection criteria, but chocolate spot may not have been specifically selected for (Anonymous, 2002).

Based on the findings of this study, tannin content does not influence resistance to chocolate spot infection. These findings are in agreement with Helsper et al. (1994) who concluded that resistance to chocolate spot is not influenced by the presence or absence of condensed tannins, as tannins do not accumulate in the tissues affected by the disease.

2.4.5 Leaf Drop Assessment

Significant leaf drop occurred in 2001 when extremely wet conditions existed at the end of July. Finch-Savage and Elston (1977) indicated that leaf death, in faba bean, is increased when the plants are under excess moisture conditions. Leaf drop in 2001 may also be explained by premature *Botrytis* induced leaf fall (Gondran, 1983). *Botrytis* is the causal agent of chocolate spot, and relatively high levels of chocolate spot and leaf drop were observed in 2001. This is supported by the fact that Earlibird, the cultivar with the highest levels of leaf drop, also experienced the highest levels of chocolate spot infection.

In 2002, when drought conditions existed at both locations, leaf drop was minimal. This can be attributed to the dry soil conditions and the relatively low levels of chocolate spot infection (Finch-Savage and Elston, 1977).

Leaf drop was most severe with the early seeding date and it declined as seeding was delayed. Similarly, leaf drop was most severe at high seeding rates and declined as seeding was reduced.

Premature leaf drop may have been influenced by *Botrytis* infection as chocolate spot infection had a similar response to seeding date. At both locations leaf drop and chocolate spot infection decreased as seeding was delayed. Premature *Botrytis* induced leaf fall explained by Gondran (1983) may also explain the effects of seeding date on leaf drop.

Earlibird and Snowbird had the highest levels of premature leaf drop while Blitz and Cresta had lower levels of premature leaf drop. At Neerlandia in 2001, Earlibird had the highest chocolate spot infection levels and was the only cultivar to

experience leaf drop at all three seeding dates, this may partially explain why Earlibird had lower yields compared to the other cultivars. Blitz did not experience premature leaf drop at any seeding date and this may partially be explained by the fact that Blitz is an indeterminate cultivar and would not naturally experience leaf senescence until much later in the growing season. There is no apparent connection between tannin content of a cultivar and premature leaf drop.

2.4.6 Plant height

Evans (1959) found that in general, increasing photoperiod resulted in an increased rate of node production and increased plant height. In this experiment, plant height increased as seeding was delayed in all site years. Longer photoperiods, during the vegetative stage of the plant's growth, at the late seeding date may have resulted in increased plant height.

Plant heights decreased as seeding rates increased in 2002 (the drought year). Martiniello and Ciola (1995) found that a lack of rainfall reduces plant height in faba bean. At high seeding rates, individual plants may have been competing for water, reducing their overall growth.

Blitz was the tallest cultivar and Earlibird was the shortest cultivar in all site years. Blitz is an indeterminate cultivar with a maximum number of days to 10% flower. Earlibird had relatively few days to 10% flower and is a determinate cultivar. Pilbeam and Hebblethwaite (1990) reported that determinate faba bean cultivars were usually shorter than indeterminate faba bean cultivars. Plant height

appears to be related to the determinate/indeterminate nature of the cultivar rather than tannin content.

2.4.7 Lodging

Lodging only occurred at Neerlandia in 2001 when relatively high moisture conditions produced maximum heights and high yields. Lodging ratings were extremely variable having a 40% coefficient of variation. Lodging only occurred in two cultivars and some of the lodged plants were infected with Sclerotinia. Gomez and Gomez (1984) found that pest damage is usually spotty within agricultural research.

In our study, maximum lodging was associated with increasing plant height and maximum yields at the late seeding date. Forbes and Watson (1994) found lodging in cereals to be associated with tall plants and high yields.

Blitz and Cresta were the two lodged cultivars. Blitz is the tallest cultivar and it suffered the worst lodging damage. Cresta is a shorter cultivar but it also suffered from lodging damage. This implies that lodging is not only a problem for tall cultivars. The highest yielding cultivar, Snowbird, did not experience substantial lodging, which indicates that high yields do not always result in lodging. Differences in stem rigidity also contribute to lodging potential (Forbes and Watson, 1994), however, this was not measured in our study.

Lawes et al. (1983) suggested that faba bean lodging can be caused by disease. Lodged plants were examined for disease and a cross section of the stem revealed the presence of sclerotia indicating the presence of Sclerotinia stem rot.

Although the level of Sclerotinia infection was not measured in lodged plots, it is possible that lodging differences between cultivars is associated with susceptibility to Sclerotinia.

Lodging, within a cultivar, can be influenced by plant height, disease, or high yields. There does not appear to be a connection between lodging and tannin content of the seed.

2.4.8 Physiological Stage at Harvest

Physiological stage at the time of harvest was most advanced for faba bean plants seeded at early seeding dates. These plants had the longest growing period. Gaye and Maurer (1991) also reported that early seeding promoted an early harvest.

Seeding rate affected physiological stage at maturity in 2001 and at Neerlandia in 2002. However, there were no consistent trends. Bochniarz et al. (1986) found that increasing seeding rates accelerated seed ripening by a few days in faba bean.

There were differences in physiological stage at the time of harvest between cultivars. Earlibird is a determinate cultivar that requires a short growing season to mature and it was at the most advanced physiological stage, of all the cultivars, in three site years. Snowbird is also a relatively determinate cultivar requiring a fairly short growing season to reach maturity. Cresta requires a longer growing season to reach maturity. Blitz is a tall, indeterminate cultivar and final plant size is dictated primarily by the growing environment (Forbes and Watson, 1994). As a result, Blitz was at the least advanced physiological stage at the time of harvest.

Flowering date and maturity date are often related, with early flowering varieties having early maturity, while late flowering varieties have late maturity (Lawes et al., 1983). This pattern is true for Blitz and Earlibird in most site years. Lawes et al. (1983) also states that there are examples of individual genotypes which are both early flowering and late maturing. Cresta had early flowering and late maturity, whereas Snowbird had late flowering and early maturity. Based on the trends seen here genotype determines the physiological stage at harvest, not tannin content.

2.4.9 Crude Protein Content

Crude protein content was unaffected by seeding delays in 2002. Rowland (1978), McVetty et al. (1986), and Kondra (1975) also found that protein levels were largely unaffected by seeding delays. Seeding rate did not influence seed protein content in our study and this agrees with the findings of Seitzer and Evans (1973), McVetty et al. (1986), and Kondra (1975).

Picard (1977) suggested that high seed protein content may be associated with late maturity of seeds, as they have a longer time to fill. Cresta and Blitz are the cultivars with the highest crude protein contents and these two cultivars are also the last to mature, based on their physiological stage at harvest. Earlibird and Snowbird are relatively early maturing cultivars and they have a lower seed protein content. There was no apparent connection between tannin content of the seed and crude protein content.

In faba beans, there is generally a positive relationship between protein content and seed weight, however, this correlation is only true within a given cultivar (Sjodin, 1981). Cresta had the largest seed weight of the four cultivars tested and it also had the highest crude protein content. Blitz, however, had the smallest seed weight of the four cultivars but it had the second highest crude protein content.

Bond (1970) found that high protein content in faba beans does not necessarily imply low yielding ability of a cultivar. For example, Earlibird is the lowest yielding cultivar but it also has the lowest protein content.

2.4.10 Soil Nutrient Changes

Faba beans may be included in crop rotations for their nitrogen benefit (Roughley et al., 1983). Duke (1981) reported that faba bean can contribute up to 50 kg ha^{-1} of residual nitrogen. At Legal in 2002, nitrate-N levels increased from 28 to 73 kg ha^{-1}, whereas the increase was much smaller at Neerlandia from 8 to 9 kg ha^{-1} (Appendix I, Table I-5). Thus, faba beans have a nitrogen benefit for subsequent crops.

2.4.11 Cultivar Performance

The results from this study indicate that the optimum agronomic production system is different for each cultivar, and this is independent of the tannin content. However, differences in cultivar performance are more dependent on the determinate or indeterminate nature of the cultivar. The following is a description of the optimum agronomic production system suggested for each cultivar.

Earlibird is a tannin-containing, determinate cultivar which yielded well under extreme drought conditions, but yielded poorly, in comparison to other cultivars, under less stressful growing conditions. To achieve high yields under drought conditions, Earlibird required a high seeding rate of 43 to 65 plants m^{-2} (Figure 2.25). Earlibird did not suffer from plant population losses when soil conditions were wet and cool. This determinate cultivar flowered early in the growing season and also matured early. A problem with this cultivar was its susceptibility to chocolate spot infection, which under high infection levels, resulted in premature leaf drop and may have possibly contributed to reduced yields. Although this cultivar performed well under drought conditions and matured early, it had a low crude protein content and this combined with its tannin content makes Earlibird unsuitable as a protein feed source for monogastric animals.

Blitz is a tannin-containing cultivar, which achieved relatively high yields in all growing environments. This indeterminate cultivar required a longer growing season to mature, and therefore early seeding was necessary to achieve maximum yields. Plant populations of this cultivar were high under all growing environments, and this could be attributed to its small seed size and tannin content. Blitz flowered and matured late. There was very little premature leaf drop associated with this cultivar. Blitz was the tallest cultivar and it also exhibited the most lodging. The high yield and high protein content of this cultivar make it ideal

as a protein source. However, the requirement of a long growing season and the tannin content of the seed are major drawbacks for this cultivar.

Snowbird is a tannin-free cultivar, which yielded poorly under drought conditions but was one of the best yielding cultivars when growing conditions were less stressful. To achieve higher yields under drought conditions, Snowbird required a high seeding rate. This cultivar suffered from plant population losses when soil conditions were wet and cool, but this only resulted in yield losses when extreme drought conditions existed (Legal, 2002). Snowbird was a late flowering cultivar, but matured relatively early. This cultivar had the highest protein yields per hectare, due to its high yields and moderate protein content. Overall, Snowbird performed the best of all the cultivars tested. Its protein content, high yields, early maturity, and tannin-free seeds make it well suited to any market.

Cresta is a tannin-free cultivar, which had moderate yields in all growing environments. To achieve higher yields under drought conditions, Cresta required a high seeding rate. Plant populations of this cultivar were poor under all growing environments, and this could be attributed to its large seed size and tannin-free seed content. This cultivar flowered early but matured late. Although Cresta had the highest seed crude protein contents, its lower yields do not make it the highest protein yielding cultivar. Cresta's high protein content and tannin-free status make it a good choice for a feed source for monogastric animals. However, poor agronomic performance, including low plant populations, late maturity, and low yields make it a less desirable choice compared to Snowbird.

2.5 Conclusions

Optimal yields were achieved at the mid seeding date, when seeding ranged from April 25th to May 14th in 2001 and from May 8th to May 27th in 2002. Tannin content of the seed did not appear to influence yield in this study, rather the determinate/indeterminate nature of the cultivar appeared to strongly influence a cultivars response to altered seeding date and seeding rate. Under average growing conditions (2001), yield was largely unaffected by seeding rates ranging from 32 to 65 plants m^{-2}. Therefore, under average growing conditions, a seeding rate of 32 plants m^{-2} could be used to achieve optimal yields while reducing seeding costs. Under drought conditions (seen in 2002), however, higher seeding rates were required for most varieties to achieve maximum yields.

Seed crude protein content decreased as seeding was delayed. Rowland (1978), McVetty et al. (1986), and Kondra (1975) found that protein levels were largely unaffected by seeding delays. Seeding rate did not influence seed protein content and this agrees with the findings of Seitzer and Evans (1973), McVetty et al. (1986), and Kondra (1975).

Tannin content did not influence most measured agronomic characteristics in this study, the exception being plant population when seeding conditions were wet and cool. Under these conditions, tannin-free cultivars had lower plant populations compared to the tannin-containing cultivars. This did not, however, result in yield decreases for the tannin-free cultivars at Neerlandia in 2002. Yield

decreases of the tannin-free cultivars at Legal in 2002 may have been associated with the extreme drought conditions at this site, and can not only be attributed to a reduction in plant population. Based on the results from this study, tannin-free faba bean production in north central Alberta does not require a modified agronomic production system to achieve high yields and quality.

Table 2.1 Schedule of events for the experiment at Legal and Neerlandia in 2001 and 2002

	HERB	FLR	CHC	LEAF	HEIGHT	LODGE	DESIC	PHYS	HARVEST
Legal 2001	June 5	June 25	Aug 21	Aug 21	Aug 21	n/a	Sept 10	Sept 17	Sept 24
Legal 2002	June 10	June 26	n/a	n/a	Aug 17	n/a	Sept 5	Sept 9	Sept 23
Neerlandia 2001	June 8	June 22	Aug 22	Aug 22	Aug 14	Sept 16	Sept 6	Sept 10	Sept 17
Neerlandia 2002	June 7	June 27	n/a	n/a	Aug 27	n/a	Sept 12	Sept 18	Oct 1

HERB = herbicide applications, FLR = beginning assessment of days to 10% flower, CHC = chocolate spot assessment, LEAF = leaf drop assessment, HEIGHT = plant height measurements, LODGE = lodging assessments, DESIC = desiccation application, PHYS = physiological stage at the time of harvest assessment, HARVEST = harvest.

Table 2.2 Significance of Year, Location, and Year x Location for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), percent of plot that lodged (LDG), physiological stage at harvest 2001; % black stems (PHYS 2001), physiological stage at harvest 2002; % black pods (PHYS 2002), and percent crude protein (PROT).

	YLD $t\ ha^{-1}$	GAIN $kg\ ha^{-1}\ day^{-1}$	PLNT $plants\ m^{-2}$	HGT cm	LEAF 0-3	FLR days to 10%	CHC 1-9	LDG %	PHYS 2001 %blk stems	PHYS 2002 %blk pods	PROT %
Year	NS	NS	NS	**		**	**				*
Location	**	**	**	**	**	NS	NS		**	**	
YxL	**	**	NS	NS		*	*				
Mean	3.5	40	40	64	1.0	48	3.2	28	22	63	27

*, ** Significant at the 0.05.and 0.01 levels respectively.
Y = year (2001, 2002), L = location (Legal, Neerlandia)

Table 2.3 Significance of seeding date, seeding rate, and cultivar for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), percent of plot that lodged (LDG), physiological stage at harvest; % black stems (PHYS), and percent crude protein (PROT) in 2001 at Legal and Neerlandia

	YLD $t\ ha^{-1}$	GAIN $kg\ ha^{-1}\ day^{-1}$	PLNT plants m^{-2}	HGT cm	LEAF[1] 0-3	FLR days to 10%	CHC[1] 1-9	LDG[1] %	PHYS %blk stems	PROT %
Legal 2001										
Date	NS	NS	NS	**	**	**	NS		**	
Rate	NS	NS	**	NS	**	NS	NS		**	
Cultivar	**	**	**	**	**	**	**		**	
DxR	NS	NS	**	NS	NS	NS	NS		**	
DxC	NS	*	NS	**	NS	**	*		**	
RxC	NS	NS	NS	NS	NS	NS	NS		NS	
DxRxC	NS	NS	NS	NS	NS	NS	NS		NS	
CV (%)	15	16	28	9	22	2	8		6	
Neerlandia 2001										
Date	**	**	*	**	**	**	**	**	**	*
Rate	NS	NS	**	NS	NS	NS	NS	NS	**	NS
Cultivar	**	**	**	**	**	**	**	**	**	**
DxR	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
DxC	**	**	**	**	**	**	**	**	**	*
RxC	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
CV (%)	9	10	20	5	23	2	6	40	8	3

*, ** Significant at the 0.05 and 0.01 levels respectively. D = seeding date, R = seeding rate, C = cultivar, CV(%) = coefficient of variation. [1] CV for these traits was based on data transformed with a square root transformation

Table 2.4 Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black stems (PHYS) at Legal in 2001.

	YLD t ha^{-1}	GAIN kg ha^{-1} day^{-1}	PLNT plants m^{-2}	HGT cm	LEAF[1] 0-3	FLR days to 10%	CHC[1] 1-9	PHYS %blk stems
Seeding Date								
Early	2.3	24	43	49	2.2	55	4.7	11
Mid	2.4	27	31	55	1.3	51	4.5	6
Late	2.5	29	29	60	0.8	48	3.9	1
se	0.3	3.2	5.4	2.3	0.04	0.4	0.08	2.0
linear	NS	NS	NS	*	**	**	NS	NS
deviate	NS	NS	NS	**	**	**	NS	**
Seeding Rates								
32	2.3	25	28	53	1.2	51	4.1	4
43	2.4	27	35	53	1.4	51	4.5	8
65	2.6	28	40	56	1.7	51	4.4	7
se	0.2	2.2	1.5	1.5	0.06	0.2	0.05	0.9
linear	NS	NS	**	NS	**	NS	NS	NS
deviate	NS	NS	*	NS	NS	NS	NS	**
Cultivar								
Blitz	2.9 a	34 a	40 a	64 a	0.9 b	56 a	3.7 c	1 c
Earli	1.8 c	19 d	34 b	48 d	2.0 a	47 c	5.2 a	15 a
Cresta	2.2 b	23 c	30 b	51 c	0.9 b	47c	4.0 c	1 c
Snow	2.7 a	31 b	34 b	54 b	1.8 a	54 b	4.6 b	7 b
se	0.1	1.0	2.2	1.5	0.07	0.2	0.04	1.4

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively. [1] se for these traits was based on data transformed with a square root transformation

Table 2.5 Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), premature leaf drop (LEAF), percent of plot that lodged (LDG), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black stems (PHYS), and percent crude protein (PROT) at Neerlandia in 2001.

	YLD t ha^{-1}	GAIN kg ha^{-1} day^{-1}	PLNT plants m^{-2}	HGT cm	LEAF[1] 0-3	LDG[1] %	FLR days to 10%	CHC[1] 1-9	PHYS %blk stems	PROT %
Seeding Date										
Early	4.3	48	46	82	1.0	9	54	5.3	51	26.8
Mid	5.0	58	39	87	0.5	29	51	5.1	44	26.7
Late	5.0	64	46	103	0.1	47	48	4.4	19	25.7
se	0.1	1.2	1.9	1.7	0.07	0.5	0.2	0.04	1.4	0.1
linear	**	**	*	**	*	**	**	NS	**	NS
deviate	*	**	NS	*	**	**	**	**	**	*
Seeding Rate										
32	4.6	55	34	90	0.4	30	51	4.8	36	26.2
43	4.8	57	41	91	0.6	26	51	5.0	32	26.3
65	4.9	58	56	91	0.5	28	51	5.1	37	26.7
Se	0.1	1.3	1.5	1.2	0.04	0.3	0.2	0.03	0.8	0.4
linear	NS	NS	**	NS	NS	NS	NS	*	**	NS
deviate	NS	NS	NS	NS	*	NS	NS	NS	**	NS
Cultivar										
Blitz	4.8 b	60 b	48 a	107 a	0.0 c	64 a	56 a	4.9 b	7 a	26.7 b
Earlibird	4.1 c	47 d	43 b	81 d	1.6 a	0 c	47 c	5.4 a	51 c	24.9 d
Cresta	4.6 b	52 c	38 c	84 c	0.1 c	45 b	47 c	4.7 b	14 b	28.4 a
Snow	5.5 a	67 a	44 b	92 b	0.4 b	5 c	53 b	4.8 b	66 d	25.7 c
se	0.1	1.3	2.0	1.0	0.05	0.4	0.2	0.03	1.2	0.3

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

[1] se for these traits was based on data transformed with a square root transformation

Table 2.6 Significance of seeding date, seeding rate, and cultivar for yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black pods (PHYS), and percent crude protein (PROT) in 2002 at Legal and Neerlandia.

	YLD t ha^{-1}	GAIN kg ha^{-1} day^{-1}	PLNT plants m^{-2}	HGT cm	FLR days to 10%	CHC[1] 1-9	PHYS %blk pods	PROT %
Legal 2002								
Date	*	*	NS	**	**	NS	**	
Rate	**	**	**	**	NS	**	NS	
Cultivar	**	**	**	**	**	**	**	
DxR	*	NS	NS	NS	**	NS	NS	
DxC	**	**	NS	NS	**	NS	**	
RxC	**	**	NS	NS	NS	NS	**	
DxRxC	NS	*	NS	NS	NS	NS	NS	
CV (%)	16	15	32	7	2	14	11	
Neerlandia 2002								
Date	NS	NS	NS	**	**	NS	**	NS
Rate	**	**	**	**	NS	*	**	NS
Cultivar	**	**	**	**	**	NS	**	**
DxR	NS	NS	NS	*	NS	NS	**	NS
DxC	**	**	NS	**	**	NS	**	**
RxC	NS	NS	NS	NS	NS	NS	NS	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8	8	27	6	2	11	16	2

*, ** Significant at the 0.05 and 0.01 levels respectively. D = seeding date, R = seeding rate, C = cultivar, CV(%) = coefficient of variation. [1] CV for this trait was based on data transformed with a square root transformation

Table 2.7 Seeding date, seeding rate, and cultivar effects on YLD (yield; t ha^{-1}), GAIN (yield gain per day; kg ha^{-1} day^{-1}), PLNT (plant population; plants m^{-2}), HGT (height; cm), FLR (days to 10% flower; from the day of seeding), CHC (chocolate spot infection; 1-9), and PHYS (physiological stage at harvest; % black pods) at Legal in 2002.

	YLD t ha^{-1}	GAIN kg ha^{-1} day^{-1}	PLNT plants m^{-2}	HGT cm	FLR days to 10%	CHC[1] 1-9	PHYS %blk pods
Seeding Date							
Early	1.2	14	38	31	50	2.1	94
Mid	1.7	20	36	36	44	1.8	57
Late	1.4	18	34	39	41	1.6	14
se	0.1	1.5	2.1	1.4	0.1	0.07	4.1
linear	*	**	NS	*	**	NS	**
deviate	NS	NS	NS	**	**	NS	**
Seeding Rate							
32	1.3	16	26	37	45	2.0	55
43	1.4	17	34	35	45	1.8	55
65	1.6	19	47	34	45	1.7	55
Se	0.1	0.6	2.1	0.7	0.1	0.03	1.4
linear	**	**	**	**	NS	**	NS
deviate	NS	NS	NS	NS	NS	NS	NS
Cultivar							
Blitz	1.6 a	20 a	38 ab	41 a	49 a	2.0 a	32 d
Earli	1.6 a	18 b	42 a	29 d	41 d	1.4 b	72 a
Crest	1.3 b	15 c	33 bc	33 c	42 c	2.1 a	53 c
Snow	1.2 b	15 c	31 c	37 b	48 b	1.9 a	62 b
se	0.1	0.6	2.7	0.6	0.2	0.05	1.6

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

[1] se for this trait was based on data transformed with a square root transformation

Table 2.8 Seeding date, seeding rate, and cultivar effects on yield (YLD), yield gain per day (GAIN), plant population (PLNT), height (HGT), days to 10% flower; from the day of seeding (FLR), chocolate spot infection (CHC), physiological stage at harvest; % black pods (PHYS), and percent crude protein (PROT) at Neerlandia in 2002.

	YLD $t\ ha^{-1}$	GAIN $kg\ ha^{-1}\ day^{-1}$	PLNT plants m^{-2}	HGT cm	FLR days to 10%	CHC[1] 1-9	PHYS %blk pods	PROT %
Seeding Date								
Early	5.8	60	46	63	50	1.8	86	28.1
Mid	5.8	63	40	72	44	1.6	82	26.8
Late	5.2	60	40	94	41	1.5	43	26.6
se	0.2	2.4	3.3	1.0	0.2	0.02	3.6	0.4
linear	NS	NS	NS	**	**	NS	NS	NS
deviate	*	NS	NS	**	**	*	**	NS
Seeding Rate								
32	5.2	57	31	78	45	1.55	65	27.0
43	5.7	62	37	77	45	1.67	72	27.0
65	5.9	65	58	74	45	1.74	75	27.4
se	0.2	1.9	2.3	1.0	0.1	0.02	1.9	0.2
linear	**	**	**	**	NS	*	**	*
deviate	NS	NS	NS	NS	NS	NS	*	NS
Cultivar								
Blitz	5.6 b	64 b	47 a	93 a	50 a	1.6 ab	58 b	27.3 b
Earlibird	5.1 c	53 d	45 a	63 d	40 d	1.7 ab	91 a	26.0 d
Cresta	5.5 b	58 c	36 b	74 c	42 c	1.8 a	45 c	28.5 a
Snow	6.1 a	70 a	40 b	76 b	49 b	1.5 b	86 a	26.8 c
se	0.1	1.2	2.7	1.1	0.2	0.04	2.7	0.2

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively. [1] se for this trait was based on data transformed with a square root transformation

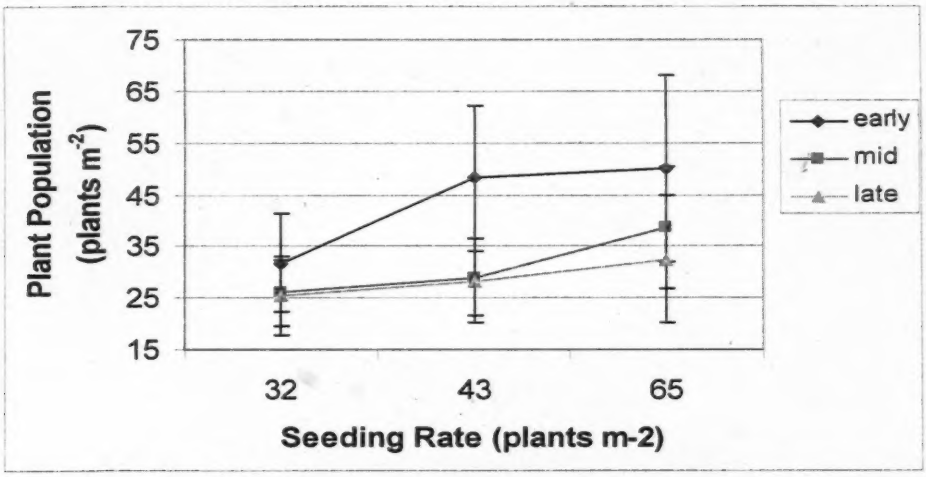

Figure 2.1: Effect of seeding rate on plant population at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$)

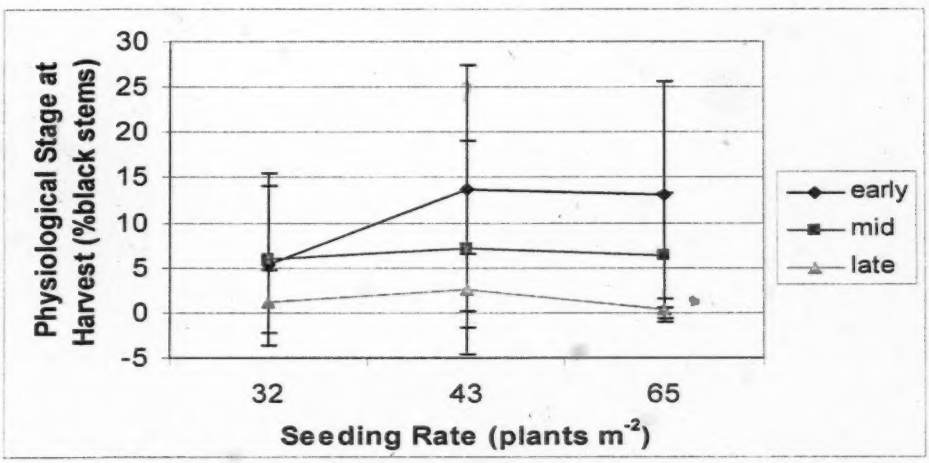

Figure 2.2: Effect of seeding rate on physiological stage at harvest, at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$)

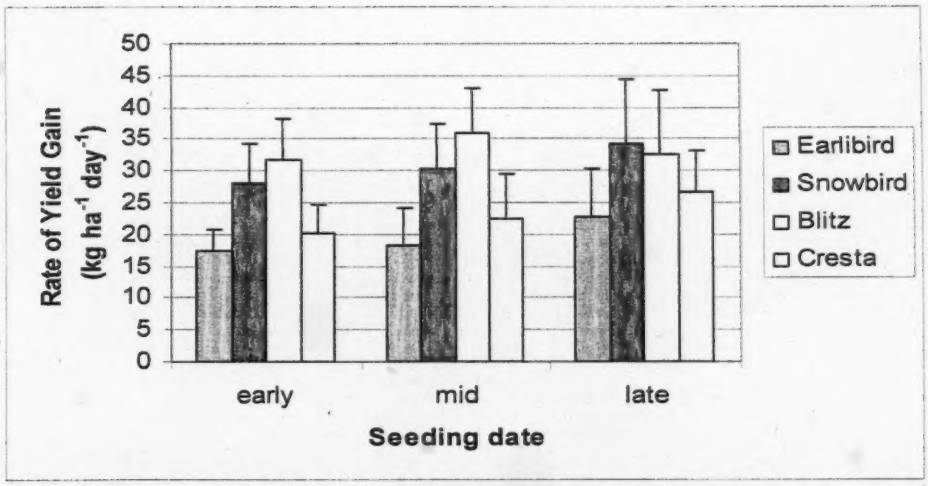

Figure 2.3: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.05$)

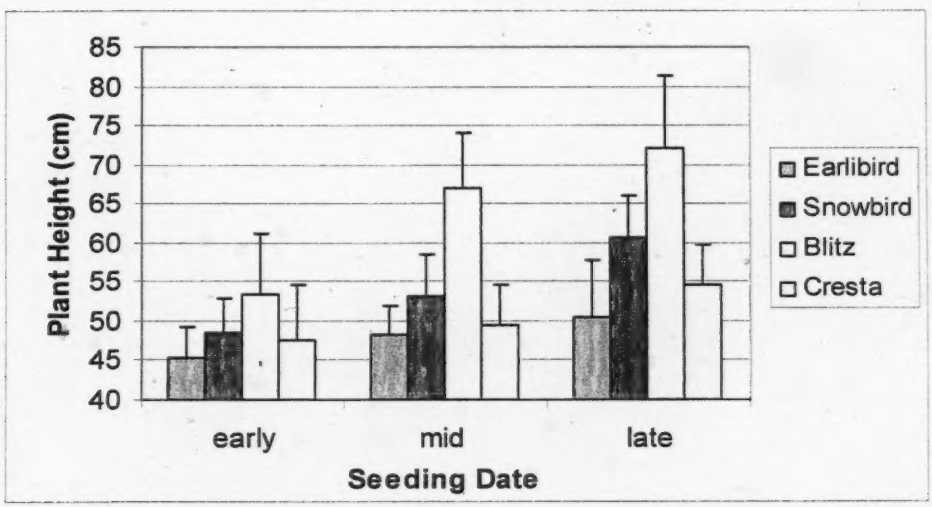

Figure 2.4: Effect of seeding date on plant height for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$)

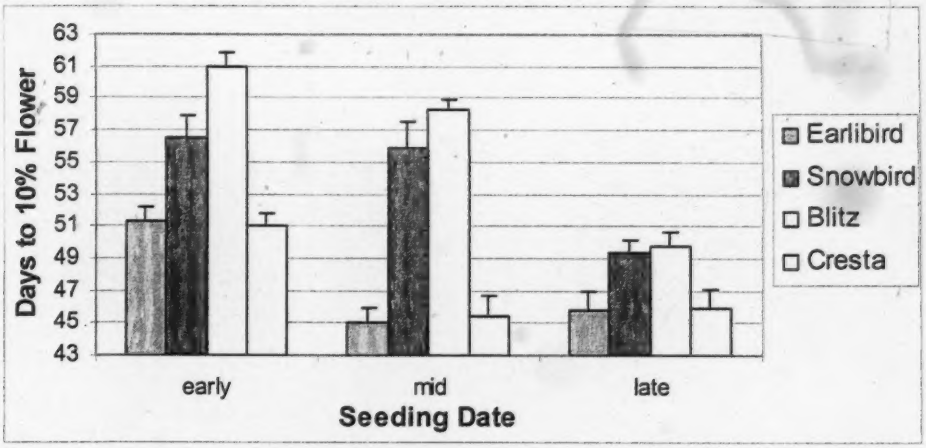

Figure 2.5: Effect of seeding date on days to 10% flower for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$)

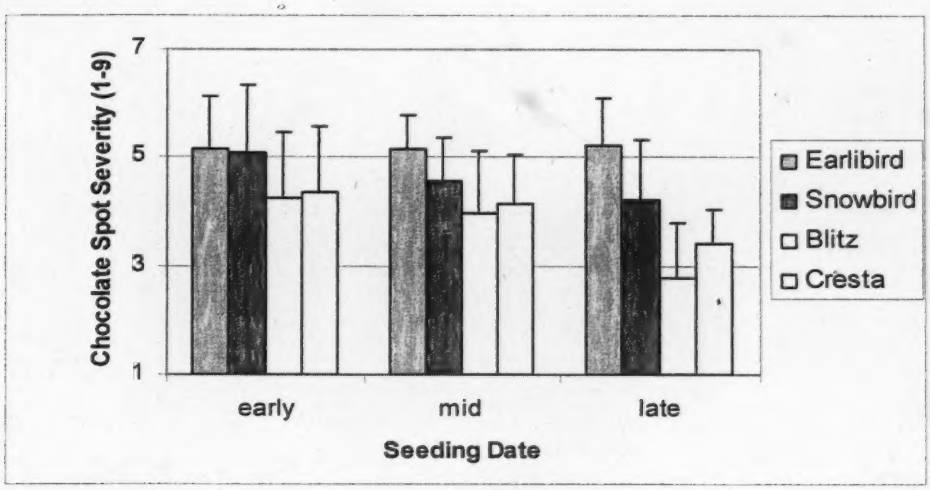

Figure 2.6: Effect of seeding date on chocolate spot severity for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.05$)

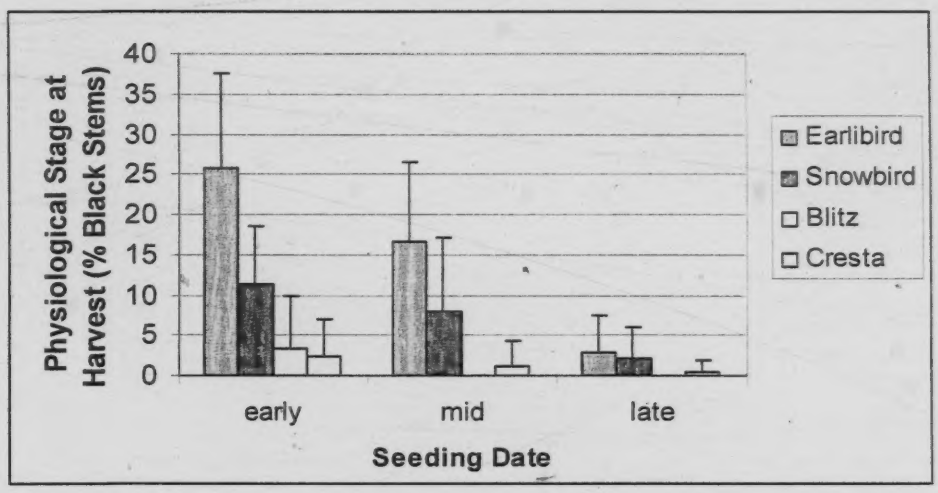

Figure 2.7: Effect of seeding date on physiological stage at harvest (percent black stems) for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$)

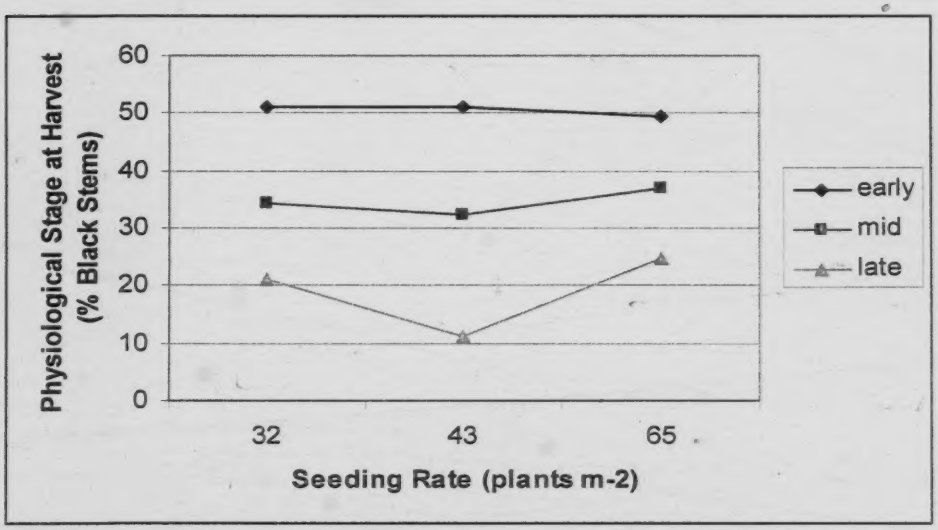

Figure 2.8: Effect of seeding rate on physiological stage at harvest (percent black stems) at three seeding dates grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate; $p \leq 0.01$).

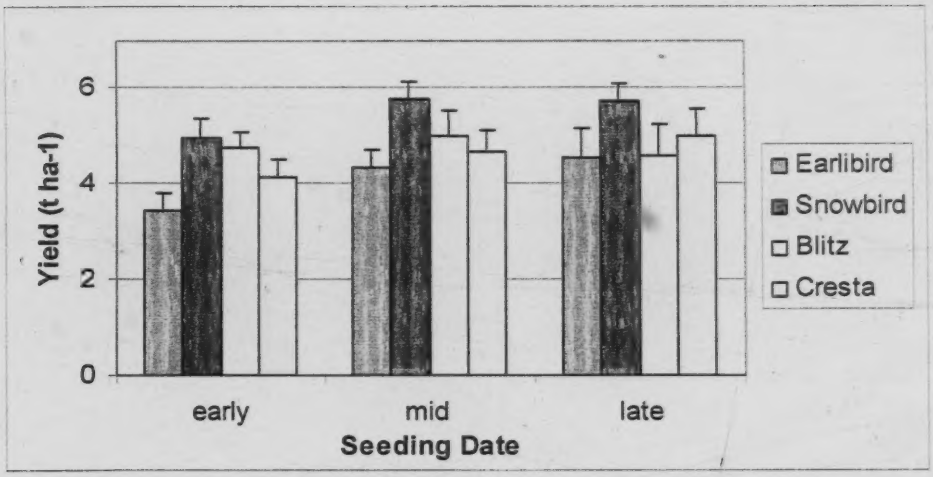

Figure 2.9: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

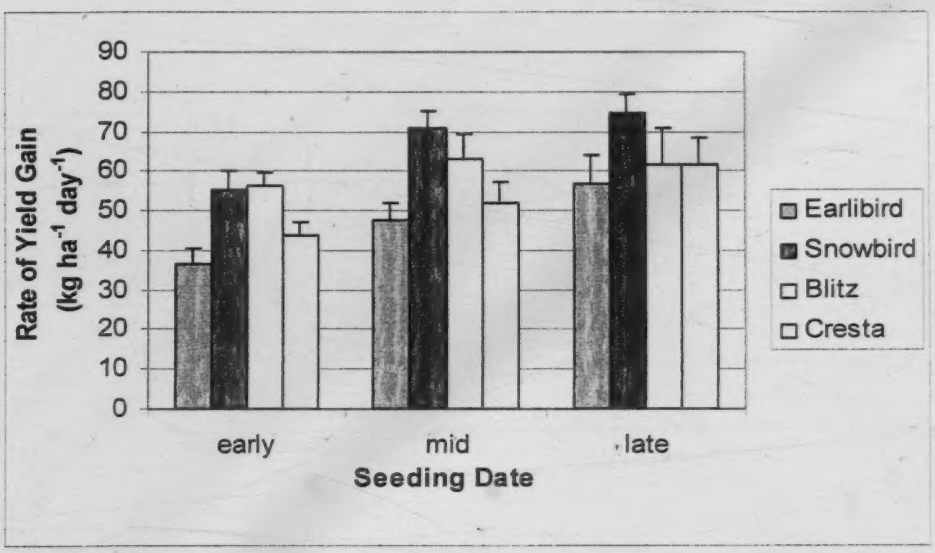

Figure 2.10: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

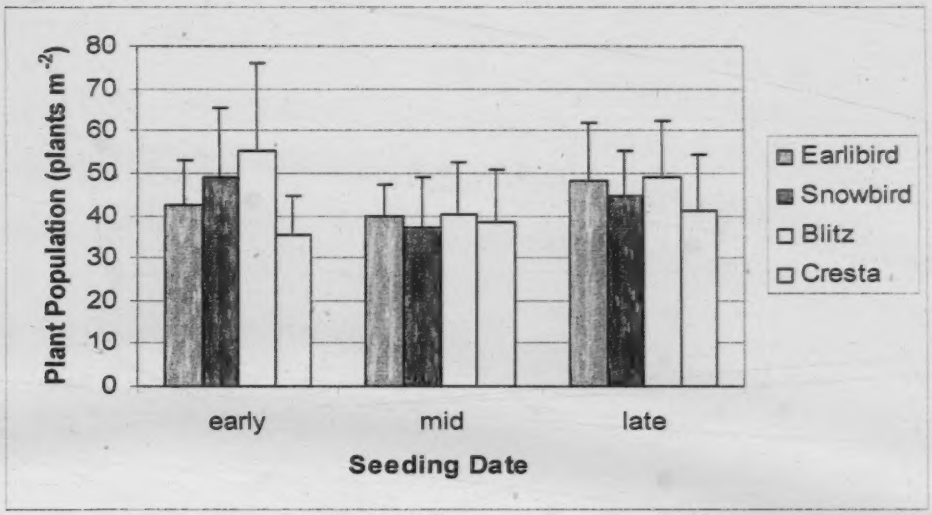

Figure 2.11: Effect of seeding date on plant population for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01).

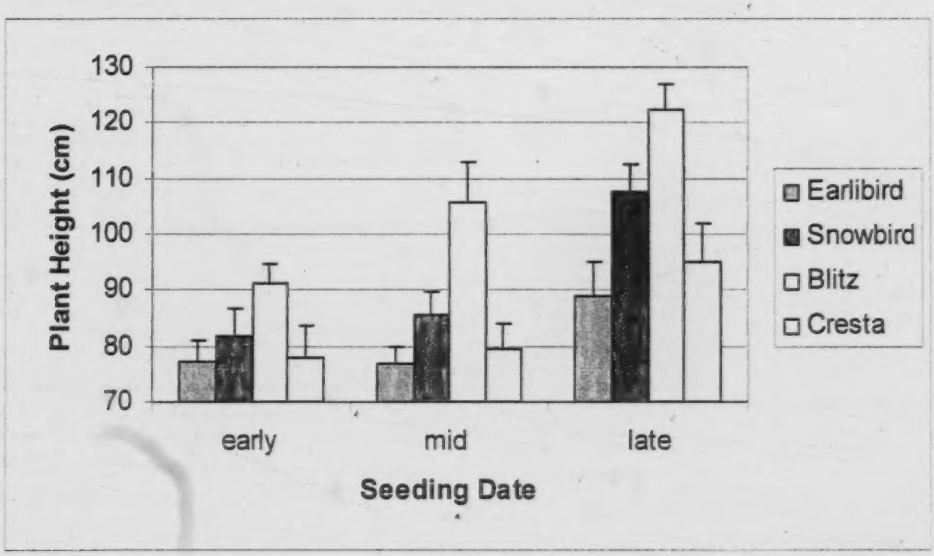

Figure 2.12: Effect of seeding date on plant height of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; p≤0.01).

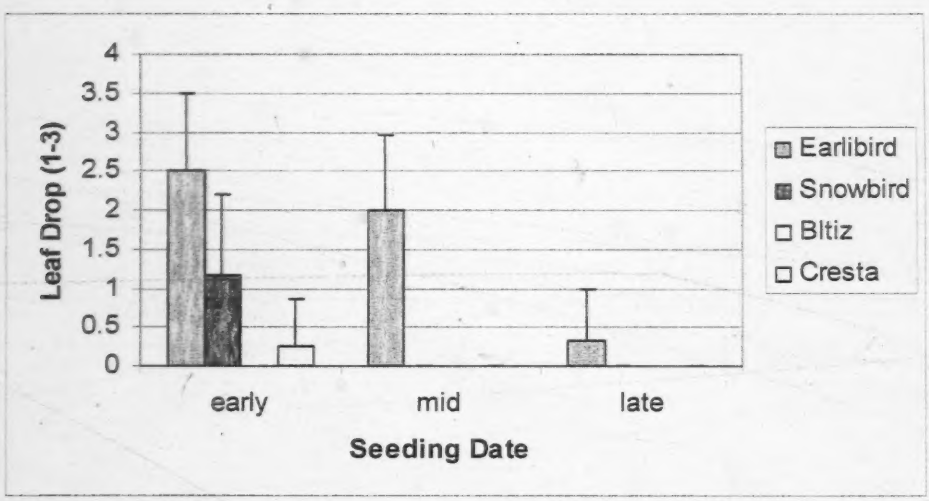

Figure 2.13 Effect of seeding date on leaf drop of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

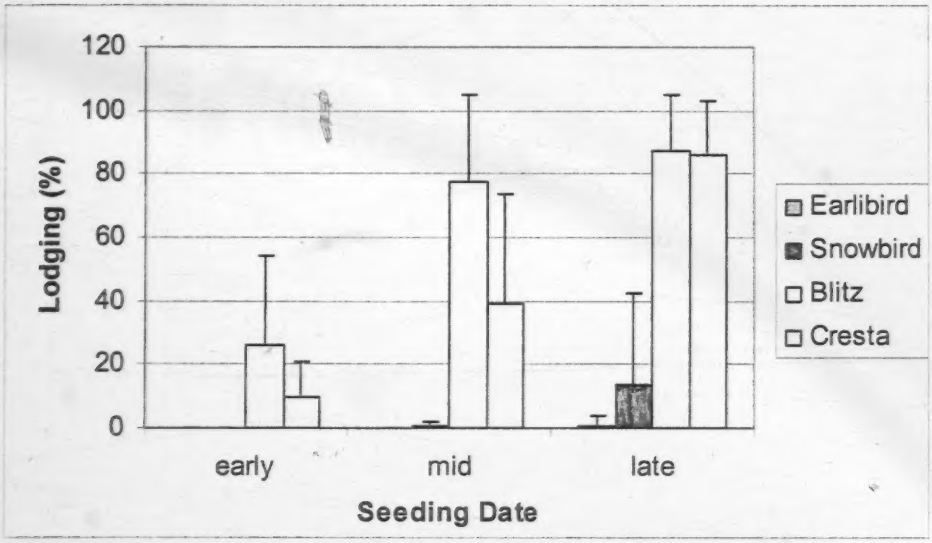

Figure 2.14: Effect of seeding date on lodging of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

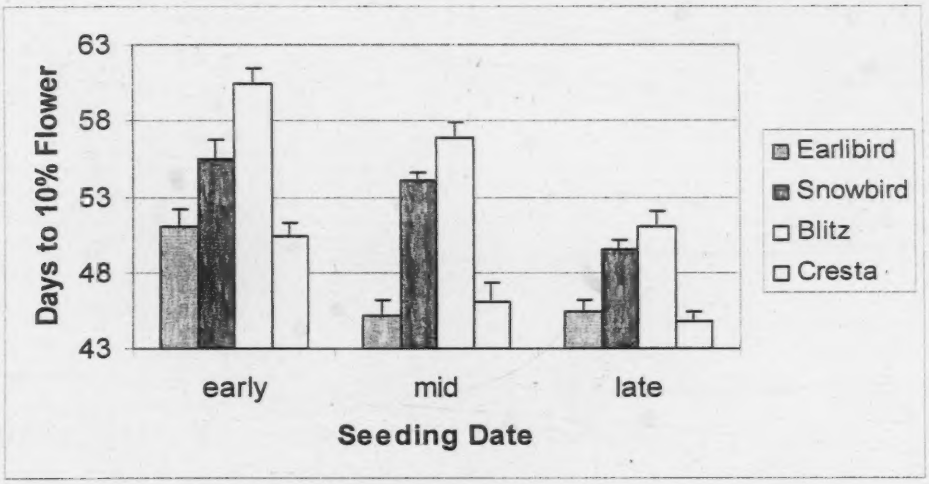

Figure 2.15: Effect of seeding date on days to 10% flower of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

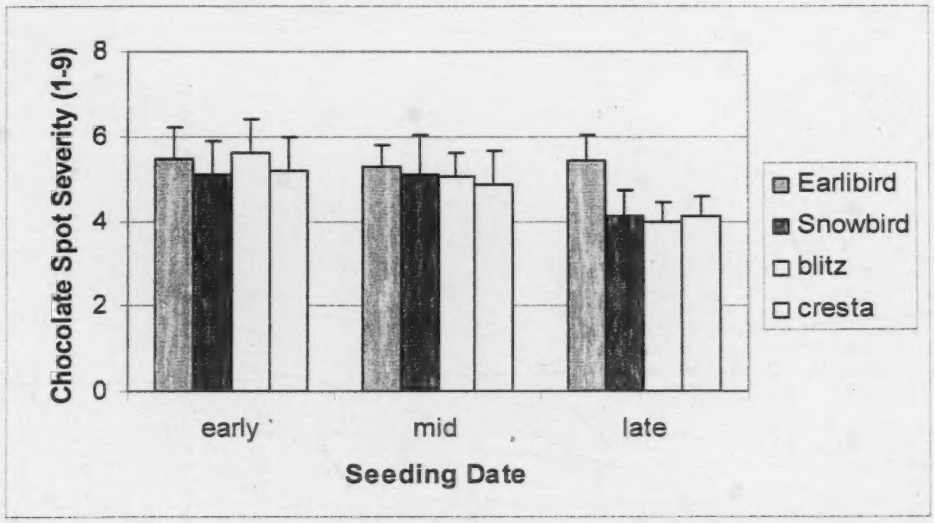

Figure 2.16: Effect of seeding date on days to chocolate spot severity of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

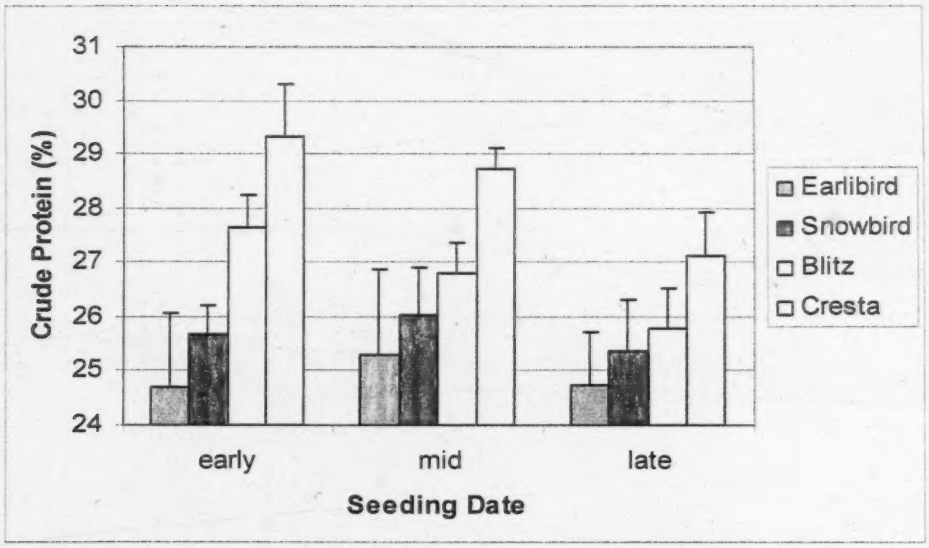

Figure 2.17: Effect of seeding date on crude protein content of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.05$).

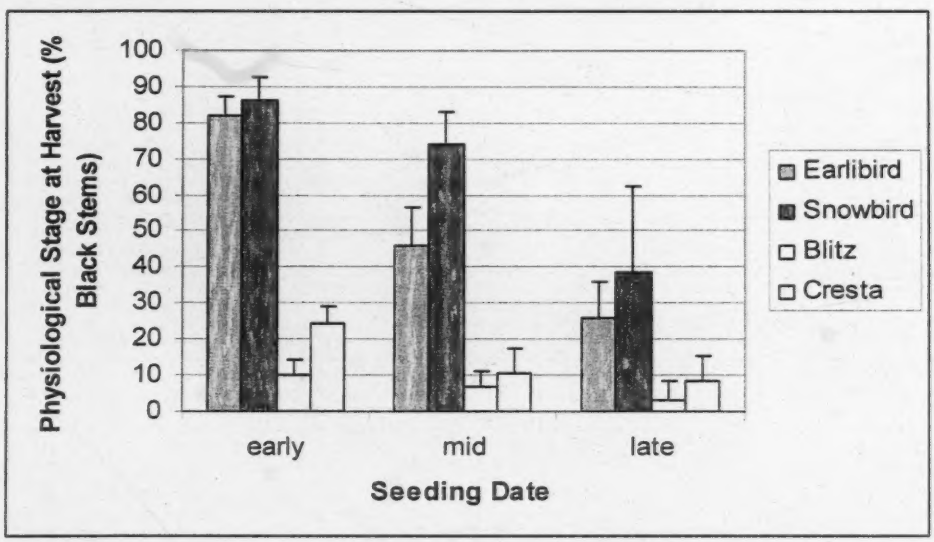

Figure 2.18: Effect of seeding date on physiological stage at harvest (% black stems) of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

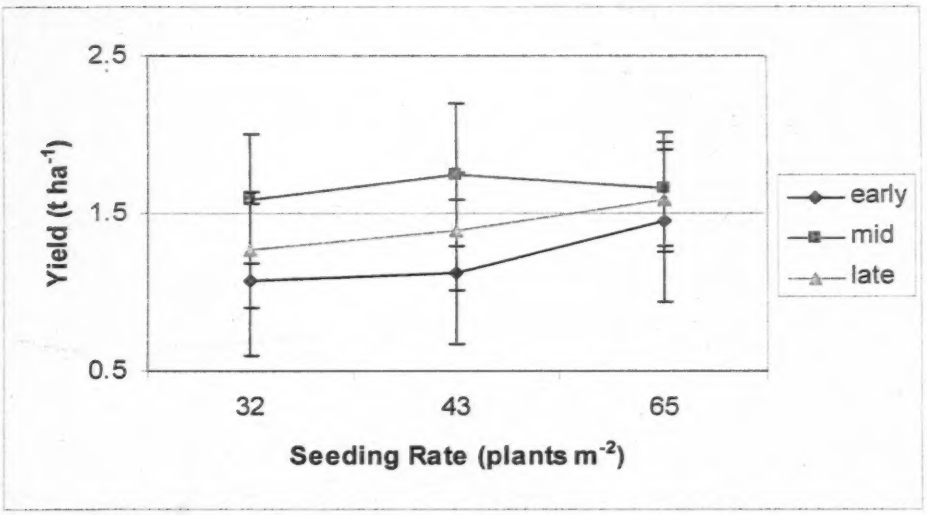

Figure 2.19: Effect of seeding rate on yield at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.05$).

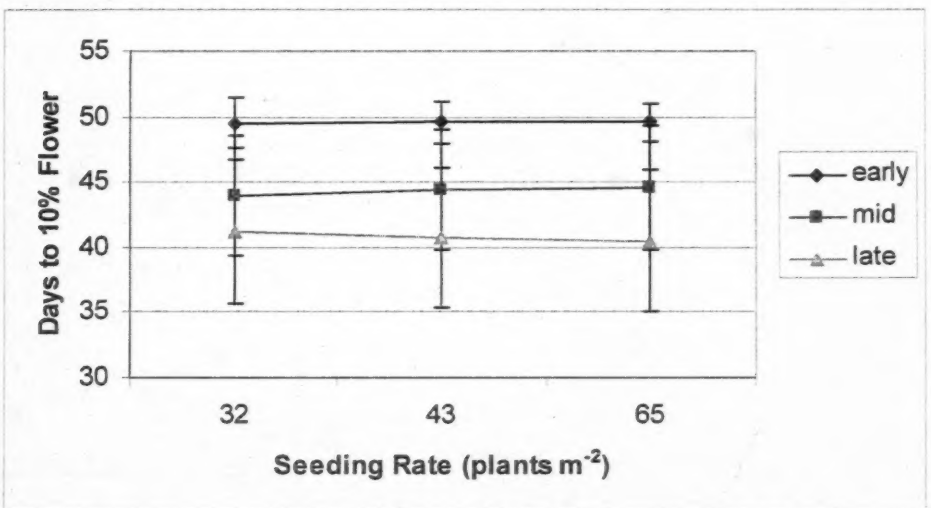

Figure 2.20: Effect of seeding rate on days to 10% flower at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

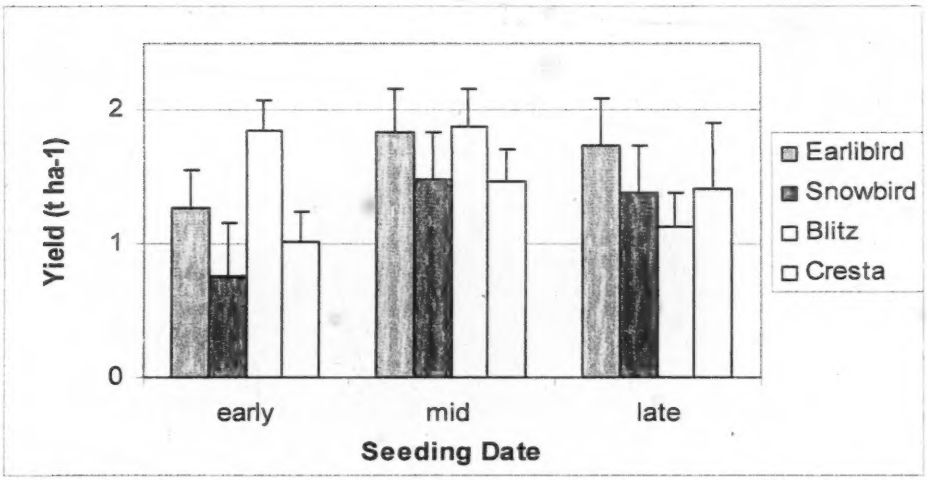

Figure 2.21: Effect of seeding date on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

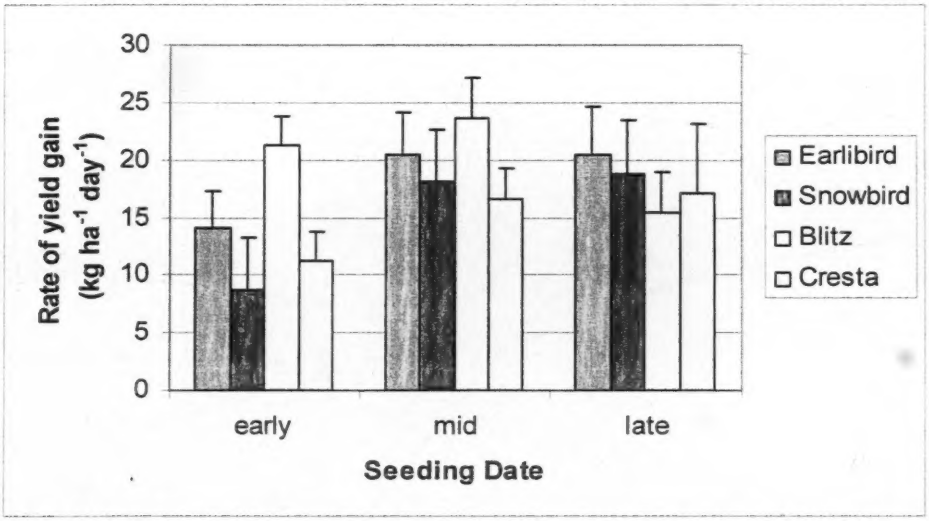

Figure 2.22: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

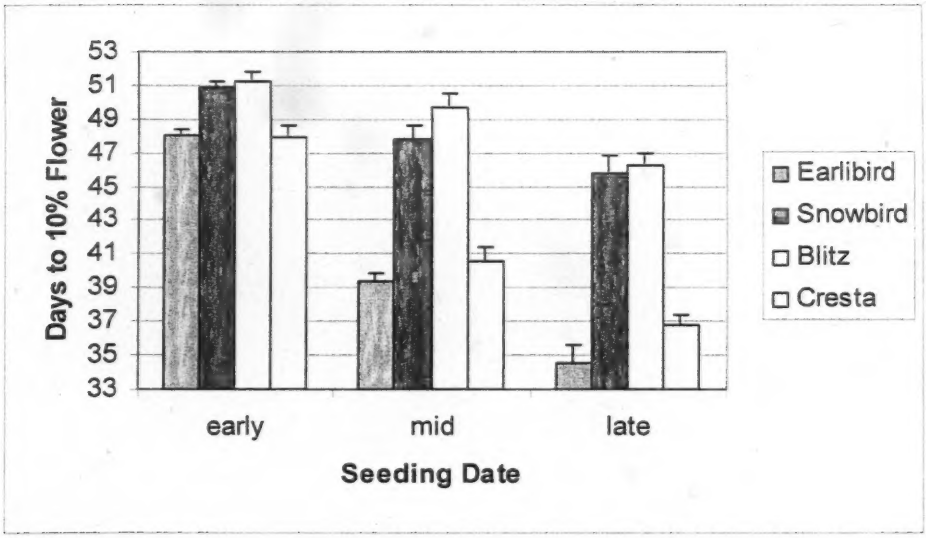

Figure 2.23: Effect of seeding date on days to 10% flower for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

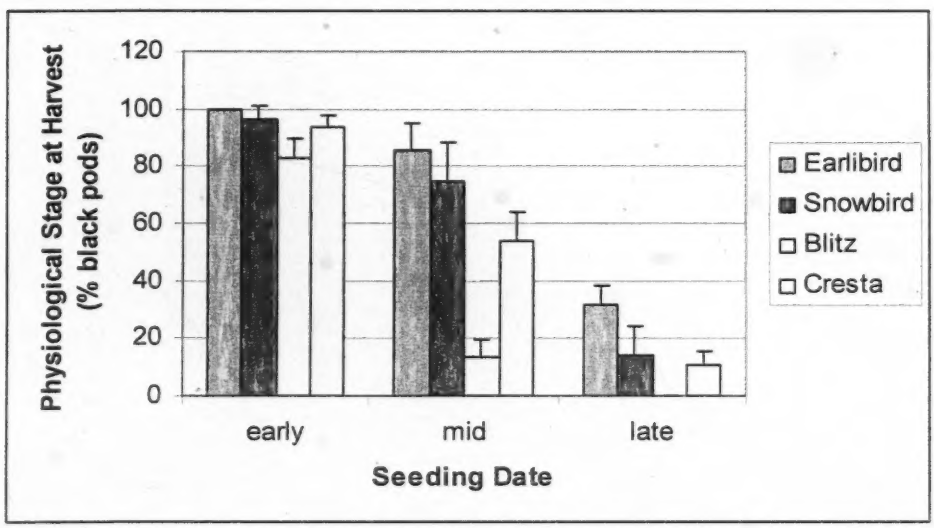

Figure 2.24: Effect of seeding date on physiological stage at harvest for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

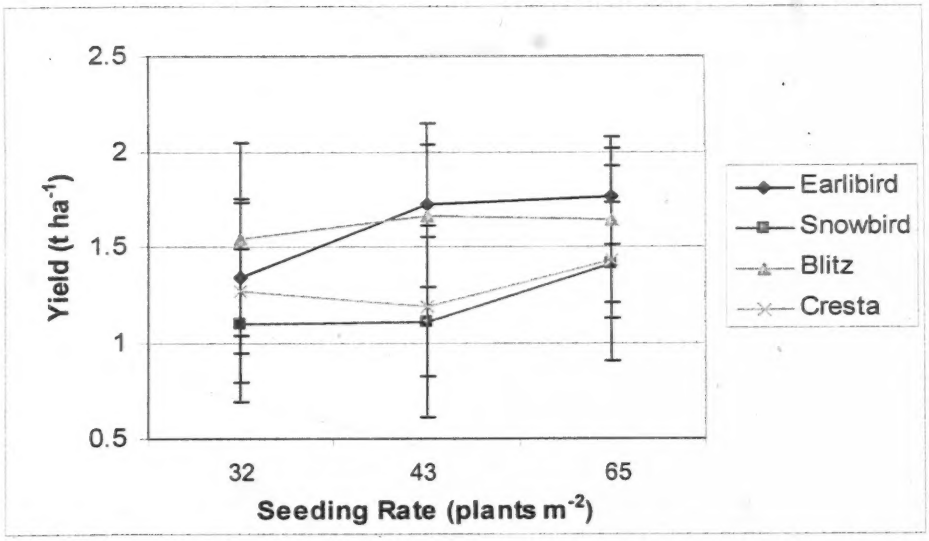

Figure 2.25: Effect of seeding rate on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; $p \leq 0.01$).

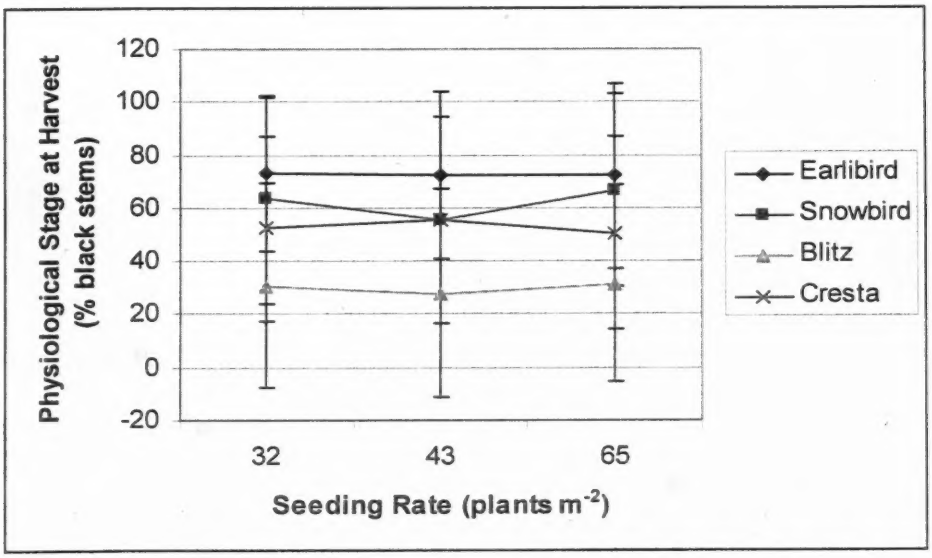

Figure 2.26: Effect of seeding rate on physiological stage at harvest (% black pods) for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; $p \leq 0.01$).

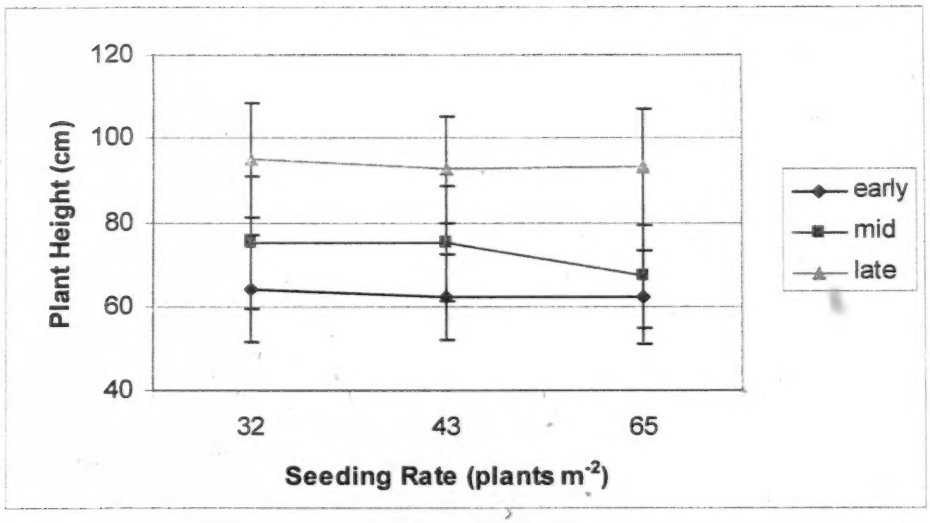

Figure 2.27: Effect of seeding rate on plant height at three seeding dates grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.05$).

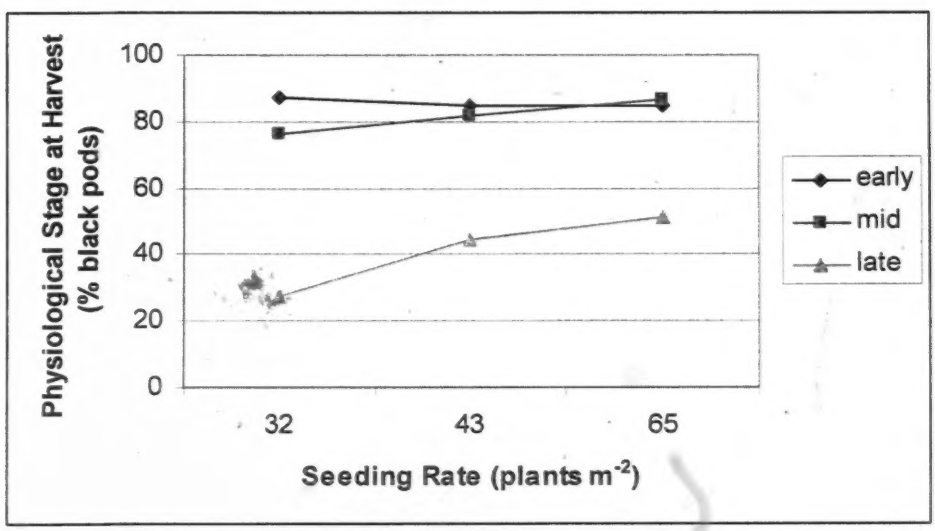

Figure 2.28: Effect of seeding rate on physiological stage at harvest (% black pods) at three seeding dates grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; $p \leq 0.01$).

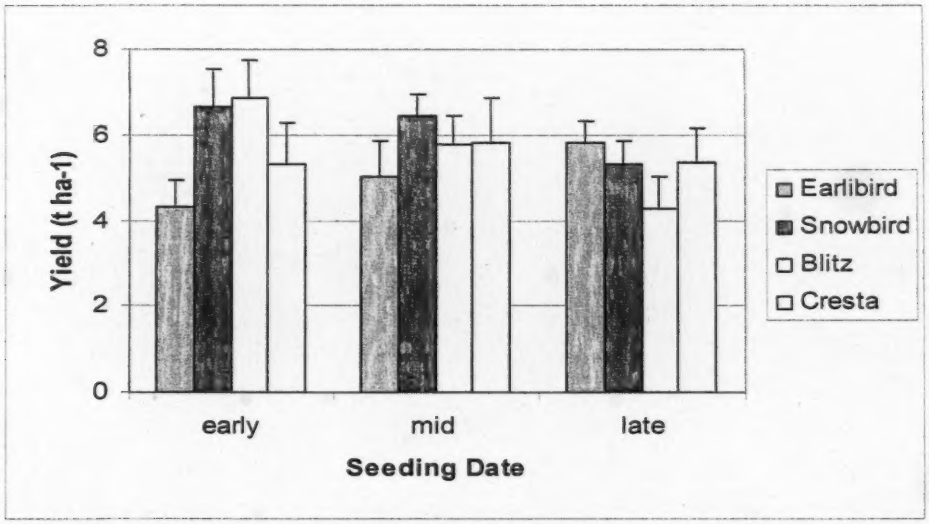

Figure 2.29: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

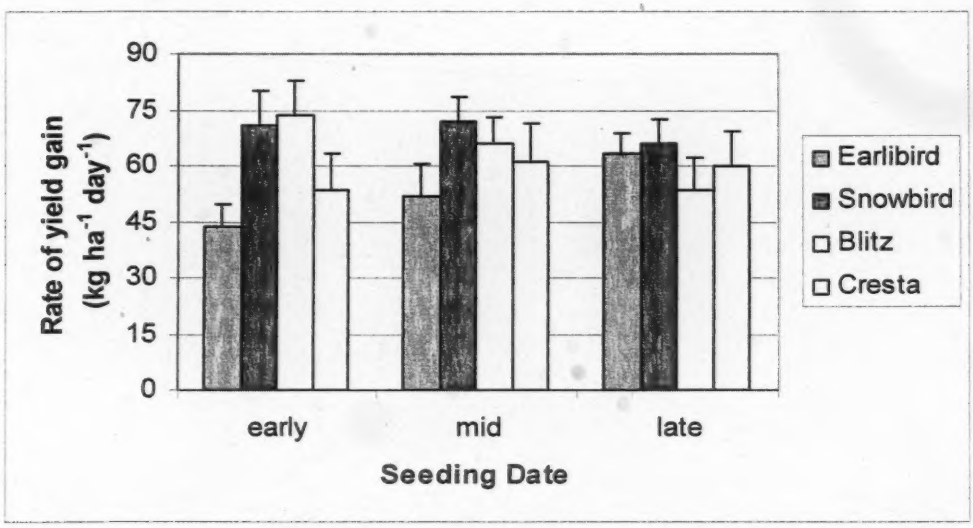

Figure 2.30: Effect of seeding date on rate of yield gain per day for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

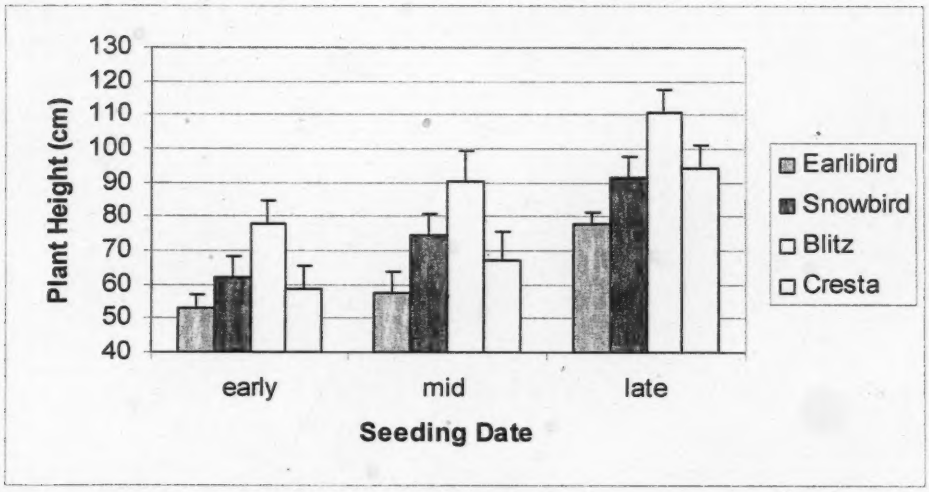

Figure 2.31: Effect of seeding date on plant height of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

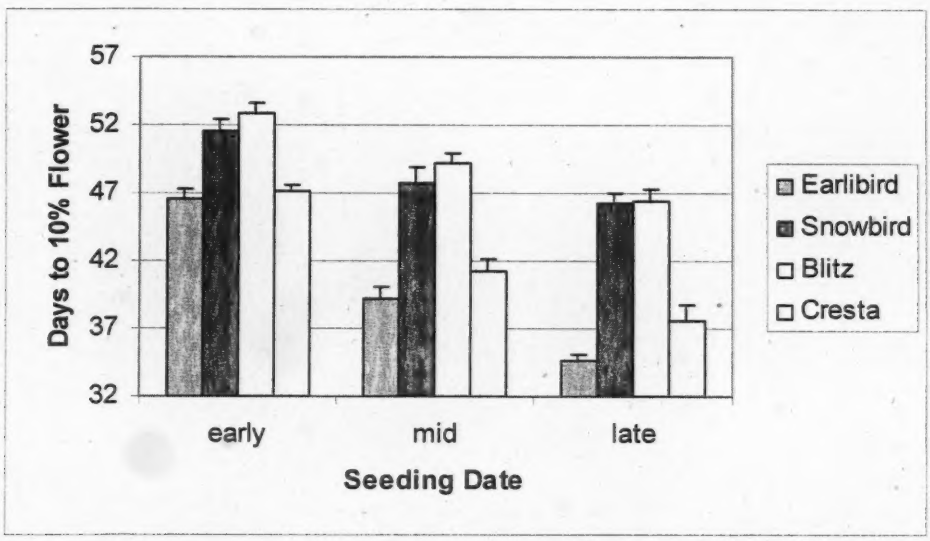

Figure 2.32: Effect of seeding date on days to 10% flower of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

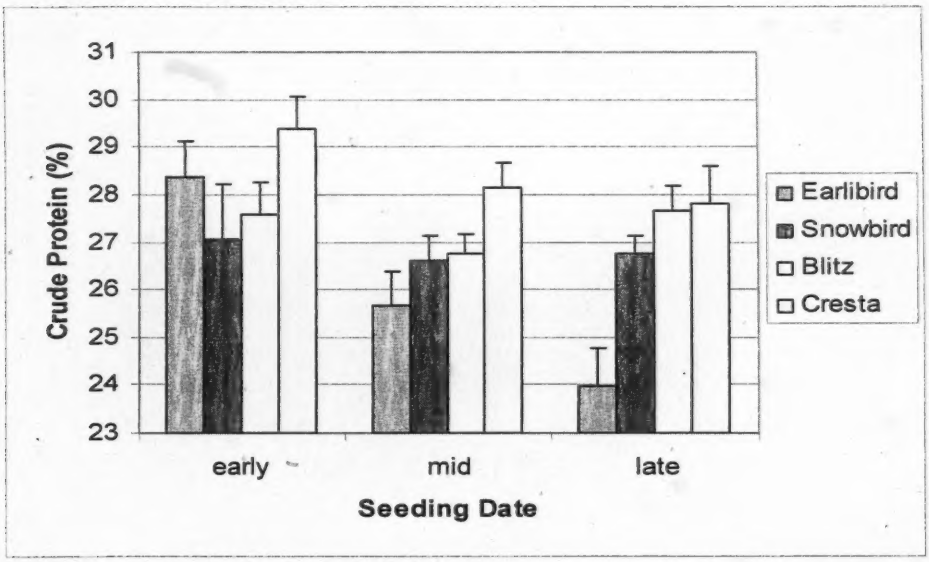

Figure 2.33: Effect of seeding date on crude protein content of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

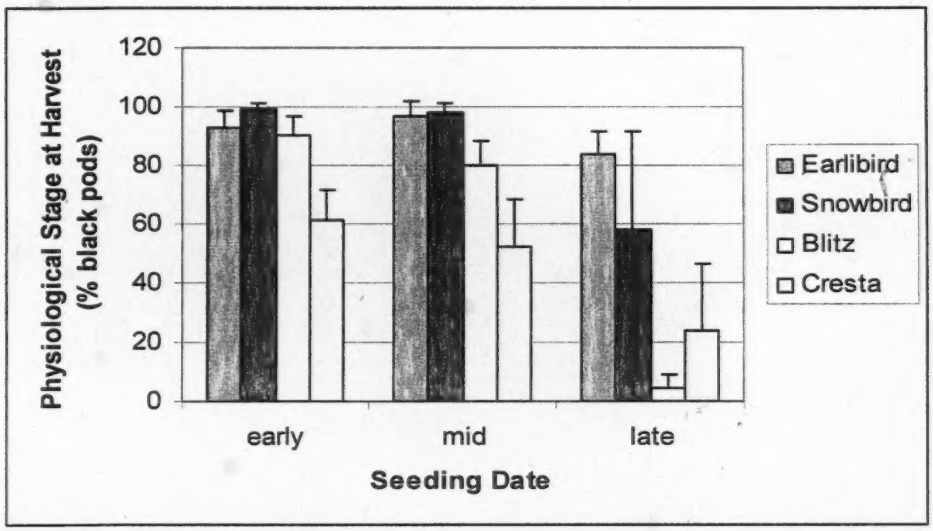

Figure 2.34: Effect of seeding date on physiological stage at harvest (% black pods) of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; $p \leq 0.01$).

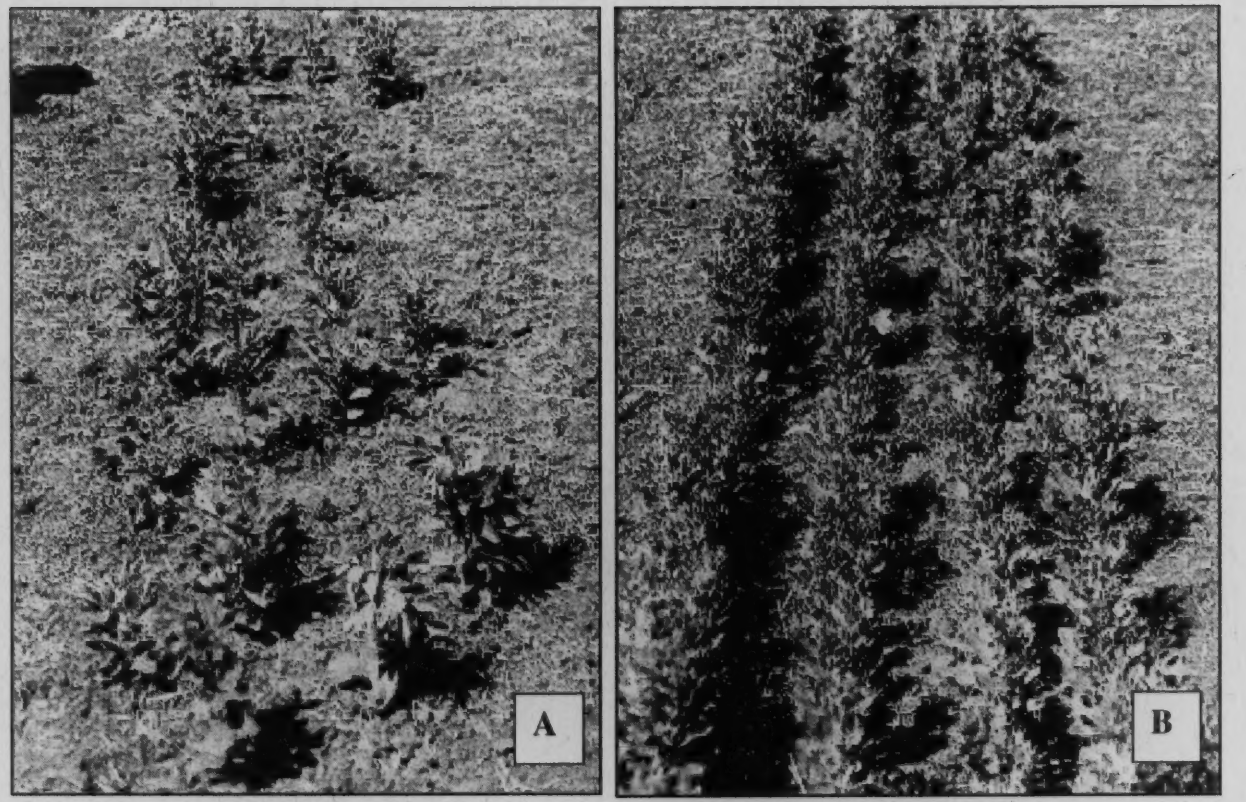

Plate 2-1: Faba bean plots on July 9, 2002 at Legal. A. Low seeding rate of 32 plants m^{-2}, B. High seeding rate of 65 plants m^{-2}. Seeding rate significant affected yield in 2002 with yields increasing (from 1.3 to 1.6 t ha^{-1} at Legal; and from 5.2 to 5.9t ha^{-1} at Neerlandia) as seeding rate increased.

Plate 2-2: Faba bean plots at Neerlandia in 2001 and 2002 indicating relative growth. A. Relative growth on August 13, 2001 at Neerlandia where average yields were 4.8 t ha^{-1}. B. Relative growth on September 12, 2002 at Legal where average yields were 5.6 t ha^{-1}.

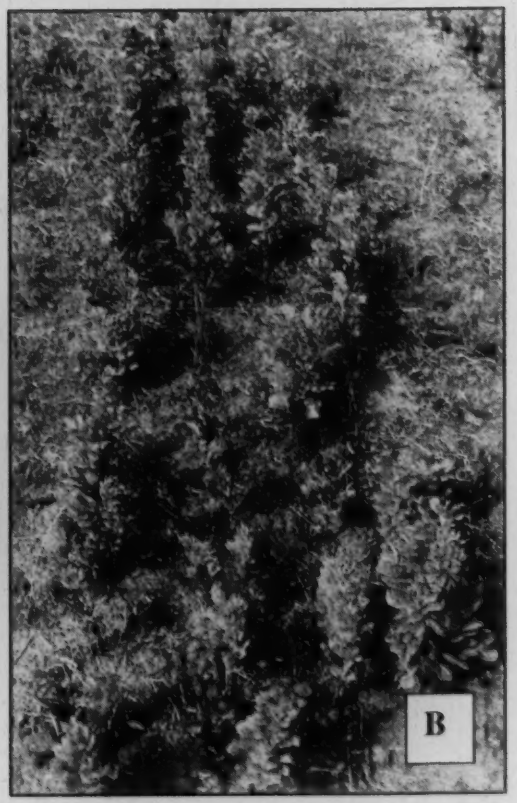

Plate 2-3: Faba bean plots at Legal in 2001 and 2002 indicating relative growth. A. Relative growth on August 29, 2001 at Legal where average yields were 2.4 t ha^{-1}. B. Relative growth on August 26, 2002 at Legal where average yields were 1.4 t ha^{-1}.

2.6 Literature Cited

Alberta Agriculture Weather Summary, 2001 and 2002. Electronic reference. Retrieved September 17, 2002. from http://www.agric.gov.ab.ca/climate

Ali, S., Calpas, J. and Bourne, J.B., eds., 2001. Crop Protection. Alberta Agriculture, Food and Rural Development Information Package Centre. Edmonton, Alberta, pp. 357-358.

Anonymous. 2002. 'Earlibird' variety description. Plant Breeders' Rights Office. Plant Varieties Journal. 42:58.

Baldwin, B. 1980. Time of sowing – a major factor influencing the yields or *Vicia faba* in South Australia. FABIS Newsletter. 2:39.

Bochniarz, J., I. Frac, M. Kasprzykowska,, A. Kawalec, M. Pelskacz, and Z. Wysocka. 1986. Productivity of faba bean as related to population density I. Development and yield components of faba bean grown for seeds. Pamietnik-Pulawski.88:141-154.

Bond, D.A. 1970. The development of field beans as a crop in Britain. Proc. Nutr. Soc. 29: 74-79.

Bond, D.A. 1976. *In vitro* digestibility of the testa in tannin-free field beans (*Vicia faba* L.). J. Agric. Sci. (Camb.) 85: 561-566.

Bond, D.A. 1977. Breeding for zero-tannin and protein yield in field beans (Vicia faba L.). In Protein Quality from Leguminous Crops, pp. 348-360. Pub. No. EUR 5686 N. Commission of the European Communities, Luxembourg.

Bond, D.A. and D.B. Smith. 1989. Possibilities for the reduction of antinutritional factors in grain legumes by breeding. In Recent Advances of Research in Antinutritional Factors in Legume Seeds (Eds. J. Hauisman, T.F.B. van der Poel and I.E. Liener), pp. 285-296. Wageriner, The Netherlands: PUDOC.

Bowser, W.E., A.A. Kjearsgaard, T.W. Peters, and R.E. Wells. 1962. Soil Survey of Edmonton Sheet (83-H). University of Alberta.

Duke, J.A. 1981. Handbook of Legumes of World Economic Importance. Plenum Press, New York.

Environment Canada. Canadian Climate Normals 1971-2000. Electronic reference. Retrieved January 28, 2003. from http://www.msc-smc.ec.gc.ca/climate/climate_normals/index_e.cfm

Evans, L.T. 1959. Environmental control of flowering in *Vicia faba* L. Annals of Botany. 23: 521-546.

Evans, L.E. and Slinkard, A.E. 1975. Production of Pulse Crops in Canada. In J.T. Harapiak, ed. Oilseed and pulse crops in western Canada – a symposium. Western Cooperative Fertilizers Ltd.

Farmzone Historical Accumulated Totals. 2001. *Electronic references*. Retrieved June 20, 2002, from http://www.farmzone.com

Finch-Savage, W.E. and J. Elston. 1977. The death of leaves in crops of field beans. Ann. Appl. Biol. 85:463-465.

Forbes, J.C. and R.D. Watson. 1994. Plants in agriculture. Cambridge University Press, Great Britain. pp.355.

Gaye, M.M. and A.R. Maurer. 1991. Modified transplant production techniques to increase yield and improve earliness of Brussels sprouts. J. Am. Soc. Hortic. Sci. 116:210-214.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research 2nd Ed. John Wiley and Sons, New York. 657pp.

Gondran, J. 1983. Sélection de la féverole pour la résistance à *Botrytis fabae*. Agronomie 3, 94. In The Pathology of Food and Pasture Legumes (ed. D.J. Allen and J.M. Lenne) pp.376. CAB International, Oxon, UK.

Griffiths, D.W. and D.I.H. Jones. 1977. Cellulase inhibition by tannins in the testa of field beans (*Vicia faba*). J. Sci. Fd. Agric. 28:983-989.

Hebblethwaite, P.D., J. Ingram, R.K. Scott, and J. Elliott. 1977. Some factors influencing yield variation of field beans (*Vicia faba* L.). In Proceedings, Symposium on the Production, Processing and Utilization of the Field Bean (*Vicia faba* L.), pp. 20-27. Ed. By R. Thompson. Bulletin No. 15, Scottish Horticultural Research Institute, Invergowrie.

Hebblethwaite, P.D., G.C. Hawtin, and P.J.W. Lutman. 1983. The husbandry of establishment and maintenance. In The Faba Bean (*Vicia faba* L.), pp.271-312. Ed. By P.D. Hebblethwaite. Butterworths, Great Britain.

Hegarty, T.W. 1977. Seed vigor in field beans (*Vicia faba* L.) and its influence on plant stand. J. agric. Sci., Camb. 88:169-173.

Helsper, J.P.F.G., A. Van Norel, K. Burger-Meyer and J.M. Hoogendijk. 1994. Effect of the absence of condensed tannins in faba beans (*Vicia faba*) on resistance to foot rot, Ascochyta blight and chocolate spot. J. Agric. Sci., Camb. 123:349-355.

Ingram, J. and P.D. Hebblethwaite. 1976. Optimum economic seeding rates in spring and autumn sown field beans. Agric. Progress. 51:27-32.

Jellis, G.J., D.A. Bond and R.E. Boulton. 1998. Diseases of faba bean. In The Pathology of Food and Pasture Legumes (Eds. P.J. Allen and J.M. Lenne). CAB International, New York, NY. pp. 371-422.

Kantar, F., P.D. Hebblethwaite and C.J. Pilbeam. 1996. Factors influencing disease resistance in high and low tannin *Vicia faba*. J. Agric. Sci., Camb. 127: 83-88.

Kay, D.E. 1979. Crop and Product Digest No. 3 - Food Legumes. Tropical Products Institute. London. 435 pp.

Knott, C.M., A.J. Biddle and B.M. McKneown. 1994. PGRO Field Bean Handbook. Processors and Growers Research Organization, Peterborough, UK.

Kondra, Z.P. 1975. Effect of row spacing, seeding rate and date on seeding of faba beans. Can. J. Pl. Sci. 55:211-214.

Lawes, D.A., D.A. Bond and M.H. Poulsen. 1983. Classification, Origin, Breeding Methods and Objectives. In P.D. Hebblethwaite (ed.) The Faba bean (*Vicia faba* L.). Butterworths, London. 573 pp.

Loomis, R.S. 1983. Crop manipulations for efficient use of water: An overview. p. 345-374. In H.M. Taylor et al. (ed.) limitations to efficient water use in crop production. ASA, CSSA, and SSSA, Madison, WI.

Marcellos, H. and G.A. Constable. 1986. Effects of plant density and sowing date on grain yield of faba bean (*Vicia faba* L.) in Northern New South Wales. Aust. J. Exp. Agric. 26:493-6.

Marquardt, R.R. 1983. Antimetabolites in faba beans: metabolic significance. FABIS. 7:1-4.

Marquardt, R.R. and A.T. Ward. 1979. Chick performance as affected by autoclave treatment of tannin-containing and tannin-free cultivars of faba beans. Can. J. Animal Sci. 59:781-789.

Martin, I., J.L. Tenorio, and L. Ayerbe. 1994. Yield, growth, and water use of conventional and semi leafless peas in semiarid environments. Crop Sci. 34:1576-1583.

Martiniello, P. and A. Ciola. 1995. Dry matter and seed yield of Mediterranean annual legume species. Agronomy Journal. 87: 985-993.

McVetty, P.B.E., L.E. Evans and J. Nugent-Rigby. 1986. Response of faba bean (*Vicia faba* L.) to seeding date and seeding rate. Can. J. Plant Sci. 66: 39-44.

Norwest Labs. 2002. Soil Test Recommendations for Faba Beans. Edmonton, AB.

Park, B. and K. Lopetinsky. 1999. Pulse Crops in Alberta. Alberta agriculture, Food and Rural Development, Edmonton, AB. pp.123-140.

Picard, J. 1977. Some results dealing with breeding for protein content in *Vicia faba*. In Protein Quality from Leguminous Crops, pp. 339-347. Pub. No. EUR 5686 N. Commission of the European Communities, Luxembourg. In P.D. Hebblethwaite (ed.) The Faba bean (*Vicia faba* L.). Butterworths, London. 573 pp.

Pieczarka, D.J. and G.S. Abawi. 1978. Populations and biology of *Pythium* species associated with snap bean roots and soils in New York. Phytopathology. 68:409-416.

Pilbeam, C.J. and P.D. Hebblethwaite. 1990. Effects of plant population on spring-sown field beans (*Vicia faba*) with different growth habits. Journal of Agricultural Science, Cambridge. 114: 19-33.

Roughley, R.J., J.I. Sprent and J.M. Day. 1983. Nitrogen Fixation. pp 233-260. In P.D. Hebblethwaite (ed.) The Faba bean (*Vicia faba* L.). Butterworths, London. 573 pp.

Rowland, G.G. 1978. Effects of planting and swathing dates on yield, quality and other characteristics of faba beans (*Vicia faba*) in central Saskatchewan. Can. J. Plant Sci. 58:1-6.

SAS Institute. 1999. Version 8.1 ed. SAS Institute, Cary, N.C.

Seitzer, J.F. and L.E. Evans. 1973. Response of small seeded faba beans to seed rate and spacing. Can. J. Plant Sci. 53:279-283.

Sjodin, J. 1981. Selection for increased protein quantity in field bean *Vicia faba*. Zeitschrift fuer Pflanzenzuechtung. 86:210-220.

Thompson, R. and H. Taylor. 1977. Yield components and cultivar, sowing date and density in field beans (*Vicia faba*). Ann. appl. Biol. 86:313-320.

Wynnyk, A., J.D. Lindsay, and Wm. Odynsky. 1696. Soil Survey of the Whitecourt and Barrhead Area. University of Alberta.

Chapter 3
Effects of Cultivar, Seeding Date, and Seeding Rates on Faba Bean Yield Components

3.1 Introduction

The three classical yield components of a faba bean plant are number of pods per plant, number of seeds per pod, and seed size (Rowland, 1955). Yield for a given area is therefore dependent on these variables and the number of plants per unit area. The number of plants per unit area is a function of the initial seeding rate, seedling mortality and the number of seedlings that survive to maturity (Forbes and Watson, 1994). The maximum yield potential will then be decreased by plant death, flower and pod abscission, and ovule abortion (Anderson et al., 1986). All of these factors and their contribution to yield are affected by the environment and growing conditions (Spaner et al., 2000).

Kambal (1969) found the number of pods per plant to account for 95-98% of yield variability in faba beans. This yield component depends on the number of fertile nodes per plant which is a function of the number of tillers produced, the number of tillers which are fertile and finally the number of fertile tillers which survive to produce seed (Forbes and Watson, 1994). The number of pods per plant also depends on the number of pods per pod-bearing node. Thompson and Taylor (1977) found that seeding date did not significantly affect pods per pod-bearing node, but values declined as seeding density was increased (Thompson and Taylor, 1977; Pilbeam et al., 1990).

The number of seeds per pod, is generally one of the most stable components for a given faba bean cultivar (Dantuma and Thompson, 1983). Thompson and Taylor (1977) found this component to be relatively stable regardless of seeding date, or plant density (Thompson and Taylor, 1981). Number of seeds per pod can vary from less than two to eight depending on the cultivar (Chapman, 1981). Usually, plants with larger seeds tend to have more seeds per pod and smaller seeded varieties tend to have fewer seeds per pod.

The final yield component, average seed weight, varies significantly between cultivars and within a cultivar depending on environmental conditions (Picard and Berthelem, 1981). There have been many different responses of seed weight to seeding rate. Hodgson and Blackman (1956), and Day et al., (1979) found that seed size remained constant as seeding rates increased from approximately 20 to 60 plants m^{-2}. McVetty et al. (1986), and Sprent et al. (1977) found seed size to decrease as seeding rate increased. Thompson and Taylor (1977) concluded that seed size shows little response to increasing plant density and it is not necessarily linked to high yields.

The main objective of this study was to examine the effect of seeding date and seeding rate on yield components of small and large seeded faba bean cultivars grown in north central Alberta.

3.2 Materials and Methods

3.2.1 Experimental Design

See Chapter 2, Section 2.2.1 Experimental Design

3.2.2 Soil Sampling

See Chapter 2, Section 2.2.2 Soil Sampling

3.2.3 Environmental Data

See Chapter 2, Section 2.2.3 Environmental Data

3.2.4 Weed Control and Plot Maintenance

See Chapter 2, Section 2.2.4 Weed Control and Plot Maintenance

3.2.5 Plant Populations

See Chapter 2, Section 2.2.5 Plant Populations

3.2.6 Yield Component Assessment

Subsamples, of ten plants (roots and shoots), were randomly selected from each sub-sub plot in 2001 (Table 3.1). Correlations were conducted, on the 2001 data set, to compare the variability of measured characteristics based on five versus ten subsamples. Correlation coefficients ranged from 0.81 to 0.98 therefore, the number of subsamples was reduced to five plants in 2002. Measured traits were; number of tillers per plant, number of nodes per plant, number of flowering nodes per plant, number of pods per node, pods per plant, and seeds per pod.

3.2.7 Seed Yield and Seed Weight

See Chapter 2, Section 2.2.12 Seed Yield

3.2.8 Statistical Analysis

Data were analyzed with analysis of variance. Statistical analysis was completed using Statistical Analysis System (SAS Institute, 1999). Linearity and deviations from the linearity was tested on the seeding date and seeding rate data using orthogonal contrasts. Orthogonal contrast coefficients used for the seeding rate data were adjusted to compensate for the unbalanced seeding rates uses in this study. A Duncan's multiple range test was used to separate the means when there were significant differences between cultivars ($P<0.05$).

Correlations were conducted among the residuals of yield components, across all cultivars and site years. Correlations among the residuals of yield components, for Earlibird and Snowbird in all site years, were also conducted. This was conducted only on Earlibird and Snowbird as they are the two most commonly grown faba bean cultivars in north central Alberta.

3.3 Results

3.3.1 Environmental Data

See Chapter 2, Section 2.3.1 Environmental Data

3.3.2 Year and Location

Years were significantly different for tillers per plant ($P\leq0.01$), nodes ($P\leq0.01$), flowering nodes ($P\leq0.01$), pods per node ($P\leq0.01$), pods per plant ($P\leq0.01$), seeds per pod ($P\leq0.01$), and seed weight ($P\leq0.01$) (Table 3.2). Year did not significantly affect yield or plant population ($P\geq0.05$).

There were more tillers per plant (1.8 verses 1.4), nodes (31 verses 21), flowering nodes (23 verses 14), pods per node (2.1 verses 1.8), pods per plant (15 verses 11), seeds per pod (3.6 verses 2.9) in 2001 than in 2002 (data not included). The average seed weight was significantly greater in 2002 (577mg $seed^{-1}$) than in 2001 (546 mg $seed^{-1}$) (data not included).

Locations were significantly different for all measured traits ($P \leq 0.01$) (Table 3.2). There was significantly more yield (5.2 t ha^{-1} verses 1.9 t ha^{-1}), plant populations (43 plants m^{-2} verses 35 plants m^{-2}), tillers (1.8 verses 1.4), nodes (28 verses 24), flowering nodes (21 verses 16), pods per node (2.1 verses 1.8), and pods per plant (18 verses 8) in Neerlandia than in Legal. There were larger seeds (580 mg $seed^{-1}$ verses 543 mg $seed^{-1}$) and more seeds per pod (3.4 verses 3.2) at Legal than at Neerlandia (data not reported).

There was a significant year x location interaction for yield ($P \leq 0.01$), nodes ($P \leq 0.01$), flowering nodes ($P \leq 0.01$), pods per node ($P \leq 0.01$), pods per plant ($P \leq 0.01$), and seeds per pod ($P \leq 0.01$) (Table 3.2). At Neerlandia, significantly higher yields occurred in 2002 (5.6 t ha^{-1}) compared to 2001 (4.8 t ha^{-1}). This trend was reversed for Legal, where 2001 yields (2.4 t ha^{-1}) were significantly higher than 2002 yields (1.4 t ha^{-1}). Due to the significant year x location interactions and differences between years and locations, all results will be presented separately for each site year.

3.3.3 Legal 2001

At Legal in 2001 seeding date had no effect on the majority of measured traits ($P \geq 0.05$) (Table 3.3). Seeding date significantly affected seed weight ($P \leq 0.01$) (Table 3.3) with seed weight decreasing (deviation $P \leq 0.01$) as seeding was delayed (Table 3.4).

Seeding rate had no significant effect on most measured traits, the exceptions being plant population ($P \leq 0.01$), and seed weight ($P \leq 0.01$) (Table 3.3). Plant populations increased (linear $P \leq 0.01$; deviation $P \leq 0.05$) as seeding rate increased (Table 3.4). Seed weight showed a significant linear trend ($P \leq 0.01$) with seed weight decreasing as seeding rate increased.

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (Table 3.3). Blitz (2.9 t ha^{-1}) and Snowbird (2.7 t ha^{-1}) had the highest yields while Earlibird (1.8 t ha^{-1}) had the lowest yield (Table 3.4). Blitz had the highest plant populations (40 plants m^{-2}). Cresta (1.8 tillers) had significantly more tillers than any other cultivar. Blitz and Snowbird had significantly more nodes and pods per node than Earlibird and Cresta. Earlibird had significantly fewer flowering nodes than the other cultivars. Blitz had significantly more pods per plant than any other cultivar (13) while Earlibird and Cresta had the fewest pods per plant (7). Blitz had significantly fewer seeds per pod (3.8) compared to the other cultivars. Cresta had the heaviest seeds (729 mg $seed^{-1}$) while Blitz had the lightest seeds (446 mg $seed^{-1}$).

The seeding date x seeding rate interaction was not significant for most measured traits the exception being plant population ($P \leq 0.01$) (Table 3.3). Plant

population increased with increasing seeding rate at all seeding dates. The early seeding date increased plant populations sharply from 32 to 43 plants m^{-2} (Figure 3.1).

The seeding date x cultivar interaction was not significant for most measured traits ($P \geq 0.05$) (Table 3.3). There was a significant seeding date x cultivar interaction for tillers ($P \leq 0.05$) and seed weight ($P \leq 0.01$).

The tillers, seeding date x cultivar, interaction showed that Cresta and Blitz had a maximum number of tillers at the early seeding date while Snowbird and Earlibird had a maximum number of tillers at the late seeding date (Figure 3.2).

The seed weight, seeding date x cultivar, interaction showed that Cresta had the heaviest seeds at the mid seeding date while the seed weight of Earlibird, Snowbird, and Blitz decreased as seeding was delayed (Figure 3.3).

The seeding rate x cultivar interaction was not significant for any measured traits at Legal in 2001 ($P \geq 0.05$) (Table 3.3). The seeding date x seeding rate x cultivar interaction was not significant for most measured traits ($P \geq 0.05$) the exception being seeds per pod ($P \leq 0.05$).

3.3.4 Neerlandia 2001

At Neerlandia in 2001, seeding date did not significantly affect most measured traits ($P \geq 0.05$) the exceptions being: yield ($P \leq 0.01$), plant population ($P \leq 0.05$), and seed weight ($P \leq 0.01$) (Table 3.3).

Yield increased as seeding was delayed from the early to mid seeding dates and then plateaued (linear $P \leq 0.01$; deviation $P \leq 0.05$) (Table 3.5). Plant population

was lowest at the mid seeding date (linear $P \leq 0.05$). Seed weight decreased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$).

Seeding rate did not significantly affect yield, seeds per pod, or seed weight ($P \geq 0.05$) (Table 3.3). Seeding rate affected plant population ($P \leq 0.01$), tillers ($P \leq 0.01$), nodes ($P \leq 0.01$), flowering nodes ($P \leq 0.01$), pods per node ($P \leq 0.05$), and pods per plant ($P \leq 0.01$).

Plant population followed a significant linear trend ($P \leq 0.01$) with plant population increasing as seeding rate increased (Table 3.5). Tillers per plant, nodes, flowering nodes, and pods per plant decreased as seeding rate increased (linear $P \leq 0.01$; deviation $P \leq 0.05$). Pods per node followed a significant linear trend ($P \leq 0.01$) with pods per node decreasing as seeding rate increased.

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (Table 3.3). Snowbird had highest yields (5.5 t ha^{-1}) while Earlibird had the lowest yields (4.1 t ha^{-1}) (Table 3.5). Blitz had the highest plant populations (48 plants m^{-2}) while Cresta had the lowest plant populations (38 plants m^{-2}). Cresta had more tillers than any other cultivar (2.1 tillers). Earlibird had the fewest nodes (32) and flowering nodes (24). Blitz (2.7) and Snowbird (2.6) had significantly more pods per node compared to the other cultivars. Blitz had significantly more pods per plant than any other cultivar (28), but it also had significantly fewer seeds per pod (3). Cresta had the heaviest seeds (691 mg $seed^{-1}$) while Blitz had the lightest seeds (402 mg $seed^{-1}$).

The seeding date x cultivar interaction was not significant for tillers, nodes, flowering nodes, pods per node, or pods per plant ($P \geq 0.05$) (Table 3.3). There was a significant seeding date x cultivar interaction for yield ($P \leq 0.01$), plant population ($P \leq 0.01$), seeds per pods ($P \leq 0.01$), and seed weight ($P \leq 0.01$).

The yield (Figure 3.4) seeding date x cultivar interaction resulted from differences in cultivar response at the mid and late seeding dates. Earlibird, Snowbird, and Cresta had maximum yields at the late seeding dates. Blitz had maximum yields at the mid seeding date.

The plant population, seeding date x cultivar, interaction (Figure 3.5) reflected Earlibird and Cresta maximizing plant populations at the late seeding date while Snowbird and Blitz maximized their plant populations at the early seeding date.

The seeds per pod, seeding date x cultivar, interaction (Figure 3.6) indicated that Earlibird and Cresta had more seeds per pod as seeding was delayed while Snowbird had fewer seeds per pod as seeding was delayed. Blitz had the smallest number of seeds per pod at the mid seeding date.

The seed weight, seeding date x cultivar, interaction (Figure 3.7) reflected that seed weight decreased as seeding was delayed, but this occurred at a different rate for each cultivar.

The seeding date x seeding rate, seeding rate x cultivar interaction, and seeding date x seeding rate x cultivar interactions were not significant for any measured parameter ($P \geq 0.05$) (Table 3.3).

3.3.5 Legal 2002

At Legal in 2002, seeding date had a significant effect on yield ($P \leq 0.05$), tillers ($P \leq 0.05$), nodes ($P \leq 0.01$), flowering nodes ($P \leq 0.01$), pods per plant ($P \leq 0.05$), seeds per pod ($P \leq 0.01$), and seed weight ($P \leq 0.01$) (Table 3.6). Seeding date did not significantly affect plant population or pods per node ($P \geq 0.05$).

Yield and tillers showed a significant linear trend (yield $P \leq 0.05$; tillers $P \leq 0.01$) with both increasing as seeding date was delayed from early to mid (Table 3.7). Nodes and flowering nodes increased as seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$). Pods per plant increased as seeding date was delayed. Seeds per pod increased as seeding date was delayed (linear $P \leq 0.05$; deviation $P \leq 0.05$).

Seeding rate had a significant effect on yield ($P \leq 0.01$), plant population ($P \leq 0.01$), tillers ($P \leq 0.01$), nodes ($P \leq 0.01$), flowering nodes ($P \leq 0.01$), and pods per plant ($P \leq 0.01$) (Table 3.6). Seeding rate did not significantly affect pods per node, seeds per pod, or seed weight ($P \geq 0.05$).

Yield and plant population followed a significant linear trend ($P \leq 0.01$), both increasing as seeding rate increased (Table 3.7). Tillers, nodes, flowering nodes, and pods per plant followed a significant linear trend (tillers $P \leq 0.05$; nodes, flowering nodes, and pods per plant $P \leq 0.01$) with all decreasing as seeding rate was increased.

Cultivars differed significantly for most measured traits ($P \leq 0.01$), the exception being pods per node (Table 3.6). Blitz and Earlibird had the highest yields (1.6 t ha^{-1}) while Cresta (1.3 t ha^{-1}) and Snowbird (1.2 t ha^{-1}) had the lowest yields (Table 3.7). Blitz (38 plants m^{-2}) and Earlibird (42 plants m^{-2}) had higher

plant populations than Cresta (33 plants m^{-2}) and Snowbird (31 plants m^{-2}). Cresta had significantly more tillers than any other cultivar (1.3 tillers). Snowbird had the most nodes (25) and Cresta had the least (20). Blitz and Snowbird had the most flowering nodes (15) while Cresta had the least (13). Blitz (7.4) and Snowbird (6.4) had significantly more pods per plant compared to Earlibird (4.5) and Cresta (4.6). Blitz, Cresta, and Snowbird (3) had significantly more seeds per pod than Earlibird (2). Cresta had the heaviest seeds (679 mg $seed^{-1}$) while Blitz had the lightest seeds (478 mg $seed^{-1}$).

The seeding date x seeding rate interaction was not significant for most measured traits, the exception being yield ($P \leq 0.05$) (Table 3.6). The yield interaction resulted from a yield decrease between the 43 and 65 plants per m^{-2} seeding rates, for the mid seeding date, while yield was increasing at the early and late seeding dates (Figure 3.8).

The seeding date x cultivar interaction was not significant for plant population, nodes, flowering nodes, pods per node, pods per plant, or seeds per pod ($P \geq 0.05$) (Table 3.6). There was a significant seeding date x cultivar interaction for yield ($P \leq 0.01$), tillers ($P \leq 0.05$), and seed weight ($P \leq 0.01$).

Yield, seeding date x cultivar, interaction showed Earlibird, Snowbird, and Cresta having maximum yields at the mid and late seeding dates. Blitz had maximum yields at the early and mid seeding dates (Figure 3.9).

Tillers, seeding date x cultivar, interaction resulted from Cresta and Blitz having maximum tillers at the mid seeding date while Snowbird and Earlibird had maximum tillers at the late seeding date (Figure 3.10).

The seed weight, seeding date x cultivar, interaction showed Snowbird and Earlibird having a maximum seed weight at the mid seeding date, while Cresta had a maximum seed weight at the late seeding date and Blitz had a maximum seed weight at the early seeding date (Figure 3.11).

The seeding rate x cultivar interaction was significant for yield ($P \leq 0.01$), and tillers ($P \leq 0.05$) (Table 3.6). There was no significant seeding rate x cultivar interaction for any other measured parameter ($P \geq 0.05$).

Yield, seeding rate x cultivar, interaction showed that yields were constant regardless of seeding rate for Blitz while Earlibird, Cresta and Snowbird had maximum yields at the high seeding rate (Figure 3.12).

Tillers, seeding rate x cultivar, interaction showed that for Snowbird and Blitz, tillers per plant decreased as seeding rate increased. For Cresta and Earlibird tillers were maximized at the mid seeding rate (Figure 3.13).

The seeding date x seeding rate x cultivar interaction was not significant for any measured parameter ($P \geq 0.05$) (Table 3.6).

3.3.6 Neerlandia 2002

At Neerlandia in 2002, seeding date did not significantly affect yield, plant population, pods per node, or pods per plant ($P \geq 0.05$) (Table 3.6). Seeding date

significantly affected tillers ($P \leq 0.05$), nodes ($P \leq 0.05$), flowering nodes ($P \leq 0.01$), seeds per pod ($P \leq 0.01$), and seed weight ($P \leq 0.01$).

Tillers per plant showed a significant linear trend ($P \leq 0.01$) with fewest tillers per plant at the mid seeding date (Table 3.8). Nodes increased as seeding was delayed (deviation $P \leq 0.01$). The fewest flowering nodes occurred at the mid seeding date (deviation $P \leq 0.01$). Seeds per pod increased as seeding was delayed (linear $P \leq 0.05$; deviation $P \leq 0.05$). Seed weight decreased when seeding was delayed (linear $P \leq 0.01$; deviation $P \leq 0.01$).

Seeding rate had a significant effect on yield ($P \leq 0.01$), plant population ($P \leq 0.01$), tillers ($P \leq 0.01$), nodes ($P \leq 0.01$), flowering nodes ($P \leq 0.01$), pods per plant ($P \leq 0.05$), and seeds per pod ($P \leq 0.01$) (Table 3.6). Seeding rate did not significantly affect pods per node or seed weight ($P \geq 0.05$).

Yield and plant population showed a significant linear trend ($P \leq 0.01$) with yield and plant population increasing as seeding rate increased (Table 3.8). Tillers, nodes, flowering nodes, pods per plant, and seeds per pod showed a significant linear trend ($P \leq 0.01$) with all decreasing as seeding rate increased.

Cultivars differed significantly for all measured traits ($P \leq 0.01$) (flowering nodes, $P \leq 0.05$) (Table 3.6). Snowbird had the highest yield (6.1 t ha^{-1}) while Earlibird had the lowest yield (5.1 t ha^{-1}) (Table 3.8). Blitz (47 plants m^{-2}) and Earlibird (45 plants m^{-2}) had the highest plant populations while Cresta (36 plants m^{-2}) and Snowbird (40 plants m^{-2}) had the lowest plant populations. Cresta had significantly more tillers than any other cultivar (1.87 tillers). Earlibird had the

fewest nodes (15.6) and flowering nodes (11.6). Blitz had the most pods per node (2.2) and pods per plant (21) while Earlibird had the fewest pods per node (1.5) and pods per plant (11). Cresta (3.2) and Snowbird (3.3) had significantly more seeds per pods compared to Blitz and Earlibird (3.0). Seed weight was greatest for Cresta (672 mg seed^{-1}) and least for Blitz (416 mg seed^{-1}).

The seeding date x seeding rate interaction was not significant for any measured parameter ($P \geq 0.05$) (Table 3.6).

The seeding date x cultivar interaction was significant for yield ($P \leq 0.01$), tillers ($P \leq 0.01$), pods per node ($P \leq 0.01$), pods per plant ($P \leq 0.01$), seeds per pod ($P \leq 0.01$), seed weight ($P \leq 0.01$) (Table 3.6). There was not a significant seeding date x cultivar interaction for nodes, flowering nodes, or plant population ($P \geq 0.05$).

The yield, seeding date x cultivar, interaction reflects yield being maximized at a different seeding date for each cultivar (Figure 3.14). Snowbird and Blitz had maximum yields at the early seeding date. Earlibird had maximum yields at the late seeding date and Cresta had maximum yields at the mid seeding date.

Tillers, seeding date x cultivar, interaction showed Cresta and Earlibird having maximum tillers at the early seeding date while Snowbird and Blitz had maximum tillers at the late seeding date (Figure 3.15).

The pods per node, seeding date x cultivar, interaction indicated that Earlibird, Snowbird and Blitz had the maximum number of pods per node at the

mid seeding date while Cresta had a maximum number of pods per node at the early seeding date (Figure 3.16).

The pods per plant, seeding date x cultivar, interaction showed that Snowbird and Blitz had a maximum number of pods per plant at the mid seeding date whereas Earlibird and Cresta had a maximum at the late seeding date (Figure 3.17).

The seeds per pod, seeding date x cultivar, interaction showed that Snowbird had a constant number of seeds per pod regardless of seeding date while the other cultivars all had an increasing number of seeds per pod as seeding was delayed (Figure 3.18).

The seed weight, seeding date x cultivar, interaction indicated that seed weight decreased as seeding was delayed but this occurred at a different rate for each cultivar (Figure 3.19).

The seeding rate x cultivar and seeding date x seeding rate x cultivar interactions were not significant for the measured traits ($P \geq 0.05$) (Table 3.6).

3.3.7 Correlations

Correlations among the residuals of yield components with yield, across all cultivars and site years, were largely not significant (Table 3.9). Correlations among the residuals were then carried out separately for Earlibird and Snowbird as they are the two most commonly grown faba bean cultivars in north central Alberta.

For the cultivar Earlibird plant population (0.39) and seeds per pod (0.19) were positively correlated with yield, while all other yield components were negatively correlated with yield (Table 3.10). For the cultivar Snowbird, seed weight (0.39) was positively correlated with yield, while all other yield components were not significant or negatively correlated with yield (Table 3.11).

3.4 Discussion

3.4.1 Response to Seeding Date

In this study, yield did not decrease as seeding was delayed, whereas numerous other authors have found this to be true (Rowland, 1978; Park and Lopetinsky, 1999; Kondra, 1975; Martiniello and Ciola, 1995; McVetty et al., 1986; Baldwin, 1980; Marcellos and Constable, 1986). Early seeding reduced yields by 0.7 t ha^{-1} at Neerlandia in 2001 and by 0.5 t ha^{-1} at Legal in 2002, compared to the mid seeding date, whereas yield was not affected by seeding date in the other site years.

Previous research found that pods per plant and yield decreased as seeding was delayed (Baldwin, 1980; McVetty et al., 1986; Rowland, 1978; Thompson and Taylor, 1977). In our study, pods per plant were generally not affected by seeding date. Differences between this study and previous studies may be due to the indeterminate nature of the cultivars used in previous studies or the longer growing season in some of the studies. In support of the importance of pods per plant as a

yield component in faba bean, Kambal (1969) found that pods per plant accounted for 95 – 98% of faba bean yield variability.

Like other studies, yield components in our study showed very little response to seeding date. On average, in this study, seeding date did not influence plant population, tiller production, pods per node (Thompson and Taylor, 1977), or seeds per pod (McVetty et al., 1986; Thompson and Taylor, 1977). We found seed weight decreased as seeding was delayed. This trend was also observed by Thompson and Taylor (1977), McVetty et al. (1986), and Rowland (1978).

Earlibird and Cresta had their highest yields at the mid and late seeding dates while Blitz had its highest yields at the early and mid seeding dates. Blitz is an indeterminate cultivar which was able to utilize the longer the growing periods following the early seeding date. Earlibird and Cresta are more determinate cultivars, and achieved high yields in a shorter growing season.

3.4.2 Response to Seeding Rate and Cultivar

3.4.2.1 Yield

Pilbeam et al. (1990) found that seed yields for a given faba bean variety were constant over a wide range of planting densities suggesting that optimum plant densities could be low, since large increases in plant density only result in small yield increases. Yield, in this study, was not affected by seeding rate in 2001, when average growing conditions existed. Although the lower seeding rates had smaller plant populations, there were more pods per plant and heavier seeds (Table 3.4, Legal; Table 3.5, Neerlandia). Therefore, under average growing conditions,

lower seeding rates may be sufficient to achieve high yields due to the flexibility of yield components in faba beans.

In contrast, yield in 2002 increased with increasing seeding rates indicating that higher seeding rates were required to achieve maximum yields under drought conditions. Knott et al. (1994) also found that higher plant populations were required on drought prone soils. The increased yields seen with increasing seeding rates were associated with increased plant populations. Individual plants, under drought conditions, were unable to manipulate their yield components to compensate for low plant populations and as a result, higher seeding rates were necessary to achieve increased yields. This was particularly true for Earlibird, Cresta, and Snowbird.

3.4.2.2 Plant populations

The number of plants per unit area is the first yield component to be determined in the growing season and it is a result of the initial seeding rate, seedling mortality and number of seedlings that survive to maturity (Forbes and Watson, 1994).

Seeding rate significantly affected plant populations, in all site years, with plant populations increasing from 30 to 50 plants m^{-2} (average of all locations) as seeding rate increased. Although this yield component was controlled by the design of the experiment, target plant populations were not met.

Plant populations were affected by soil conditions at the time of seeding. In 2001, increased seeding rates resulted in increased yields, although this effect was

not significant. When soil conditions were dry and warm at the time of seeding, in 2001, the small seeded cultivar, Blitz, had high plant populations while the large seeded cultivar, Cresta, had low plant populations. Seeds typically imbibe 1 to 2 times their own weight in water (Forbes and Watson, 1994) therefore, larger seeds require more moisture to germinate. Thus, under dry soil conditions, seed size was the primary factor determining plant population, although increasing plant populations did not significantly increase yields.

Increased seeding rates and high plant populations, in 2002, increased yields. When soil conditions were wet and cool at the time of seeding, in 2002, the tannin-containing cultivars, Earlibird and Blitz, had higher plant populations compared to the tannin-free cultivars, Snowbird and Cresta. Helsper et al. (1994) described a similar response for tannin-free faba beans.

Overall, the increase in plant population was associated with an increase in yield. Individual plants were unable to compensate for low plant populations therefore, plant population appears to be the primary yield component accounting for increases in yield.

3.4.2.3 Tillers

The production of pods and seeds is related to the number of tillers that are produced (Forbes and Watson, 1994). It was expected that plants with more tillers would have more flowering nodes, more potential pods, and potentially higher yields per plant. Increased tiller production was thought to compensate for low plant populations.

In this study, tillers per plant tended to decrease as seeding rate increased (Neerlandia 2001, Legal 2002, Neerlandia 2002). This agrees with Pilbeam et al. (1991) that high plant populations are known to decrease the production of tillers. In our test, faba beans planted at the low seeding rate compensated for smaller plant populations by increasing the number of tillers per plant. As seeding rate increased there was more intraspecific competition and therefore, fewer tillers per plant. The decrease in tiller production, seen with increasing seeding rates, was associated with a significant increase in yield at Legal in 2002 and at Neerlandia in 2002 caused primarily by the increase in plant population. Thus, reducing the amount of energy invested in multiple tillers can result in increased yield particularly when moisture is limiting.

Tillering is one of the phenotypic traits of faba bean that is poorly understood and there is little mention of it in the literature. It is assumed that tillering is a function of assimilate requirements for the development of a shoot meristem (Edwards and Beech, 1984). The assimilate requirement is determined primarily by genotype. Cresta consistently produced more tillers than any other cultivar. Cresta also had the lowest plant populations and increased tillering in Cresta may be a response to low plant populations.

Edwards and Beech (1984) suggested that tillering may also be influenced by temperature. Cresta tended to produce more tillers when cool vegetative conditions exist (at the early seeding date) while Snowbird appeared to require

warmer vegetative conditions (at the late seeding date) to initiate increased rates of tillering.

In this study, tillering was extremely variable, having coefficients of variation ranging from 45 to 119%. Tillering is a characteristic that has high coefficients of variation, in other plant species (Ayoub et al., 1994).

3.4.2.4 Total Nodes and Flowering Nodes

Although nodes and flowering nodes do not directly contribute to yield, they were thought to be an indicator of the potential for a plant to produce pods and therefore yield. In most years, nodes and flowering nodes per plant decreased as seeding rate increased. This reduction in nodes and flowering nodes at the higher seeding rates, caused by fewer tillers, did not reduce yields. This indicates that at the higher seeding rates more of the flowering nodes produced pods and seeds, which contributed to yield. At the low seeding rates, the increased number of nodes and flowering nodes, on the tillers, did not produce pods or seeds, which contributed to yield.

In all cultivars, more total nodes resulted in more flowering nodes. Snowbird and Blitz have more nodes and flowering nodes than Cresta and Earlibird. Based on the correlations for Earlibird and Snowbird increased nodes and flowering nodes, were not associated with increased yields, which indicates that not all flowering nodes produce pods and seeds.

A larger percentage of Cresta's total nodes were flowering nodes (data not included), in comparison to the other cultivars. This indicates that Cresta produces fewer vegetative nodes before it begins to flower.

3.4.2.5 Pods per Node

Increasing the number of pods per node is one means of increasing yield. In our study seeding rate did not significantly affect pods per node. However, Thompson and Taylor (1977) and Pilbeam et al. (1991) found pods per node to decrease as seeding rate increased. In the four faba bean cultivars tested, pods per node was a relatively stable yield component which is specific to the cultivar. Blitz and Snowbird had significantly more pods per node compared to Earlibird.

3.4.2.6 Pods per Plant

In our study, pods per plant decreased as seeding rate increased which agrees with Thompson and Taylor (1977), McVetty et al. (1986), and Pilbeam et al. (1990). This decrease in pods per plant was associated with an increase in yield with increased plant populations compensating for a decrease in pod production per plant.

Pods per plant differed significantly across cultivars. Blitz and Snowbird had significantly more pods per plant that Earlibird and Cresta. Therefore, Blitz and Snowbird achieved a large portion of their yield by having a large number of pods per plant.

3.4.2.7 Seeds per Pod

The number of seeds per pod has been considered a relatively stable yield component in faba beans (Dantuma and Thompson, 1983). Thompson and Taylor (1977), Ishag (1973), Seitzer and Evans (1973), and Sprent et al., (1977) all found that the number of seeds per pod were unaffected by plant density, which agrees with the general trends of our findings.

Chapman (1981) suggested that faba bean cultivars with larger seeds tend to have more seeds per pod while smaller seeded cultivars tend to have fewer seeds per pod. This trend was seen with Blitz, the smallest seeded variety having the fewest seeds per pod in three site years.

3.4.2.8 Seed Weight

Average seed weight is the final yield component. In the literature, there have been many different responses of seed weight to seeding rate. Hodgson and Blackman (1956), and Day et al., (1979) found that seed size remained constant as seeding rates increased from approximately 20 to 60 plants m^{-2}. McVetty et al. (1986), and Sprent et al. (1977) found seed size to decrease as seeding rate increased. While Thompson and Taylor (1977) found seed size to increase as seeding rate increased from 10 to 70 plants m^{-2}. In our study, seed weight was not significantly affected by seeding rate, however, seed size decreased as seeding rate increased. The variability of seed size in response to seeding rate indicates that seed size is a highly variable yield component differing with environmental conditions and genotype.

As expected, seed weight was significantly different for each cultivar. Cresta, a large seeded cultivar, consistently had the heaviest seeds and therefore achieved a large portion of its yield by producing heavy seeds. On the other hand, Blitz, a small seeded cultivar, had light seeds and depended on increasing other yield components in order to achieve its yield.

Seed weight of Cresta responded to seeding date unlike the other cultivars. At Legal, Cresta tended to slightly increase seed size as seeding was delayed, which is in contrast to the general trend in this experiment, of decreasing seed size as seeding was delayed.

3.4.3 Correlations between yield components

Faba beans build yield by initially establishing plant populations, then tillering, followed by flowering, pod set and finally seed filling (Forbes and Watson, 1994). Correlations between the residuals of these yield components with yield, across all cultivars and site years, indicated few significant results. Pilbeam et al., (1990), found that correlations of faba bean yield components were frequently small and could be accounted for by variability in values between varieties. Correlations were run separately on the two most commonly grown faba bean varieties, Earlibird and Snowbird.

Yield increases in Earlibird were achieved by increasing plant populations. Increased plant populations are associated with decreased tillers per plant, fewer nodes, flowering nodes, pods per node, and pods per plant. At high plant populations, individual Earlibird plants were smaller but they produced more seeds

per pod and the increased number of smaller plants accounted for the increased yield. Higher seeding rates may be necessary for Earlibird to achieve high yields.

For the cultivar Snowbird, seed weight was positively correlated with yield while all other yield components were not significant or negatively correlated with yield. Thus, increases in Snowbird yield appear to be associated with increases in seed weight. However, according to the seeding date x cultivar interaction for seed weight, Snowbird decreased seed weight as seeding was delayed but Snowbird yield was maximized at the mid and late seeding dates in 3 site years (Legal 2001, Neerlandia 2001, Legal 2002). Due to this discrepancy, increases in Snowbird yield were not expected to be positively correlated with seed weight.

The correlation results were not entirely consistent. In this study, yield components were measured on a per plant basis while yield and seed weight were measured on a per plot basis. Husain et al. (1988) reported that differences between plot yield and the yield based on the sum of yield components, were often substantially different. This may explain the lack of strong correlation between yield and yield components in this study.

3.5 Conclusions

In this study, yield did not decline with a delay in seeding date. The unexpected response of yield to seeding date could be explained by the unusual response of decreased pods per plant with delayed seeding. Like other studies, plant population, tiller production, pods per node (Thompson and Taylor, 1977),

and seeds per pod (McVetty et al., 1986; Thompson and Taylor, 1977) showed very little response to seeding date. In this study, seed weight decreased as seeding was delayed; Thompson and Taylor (1977) reported the same trend.

In response to increasing seeding rate, most yield components behaved in a similar manner to that reported by other authors. In this study, higher yields and higher plant populations were associated with fewer tillers (Pilbeam et al., 1991), fewer total nodes, fewer flowering nodes, fewer pods per node (Thompson and Taylor, 1977; Pilbeam et al., 1991), fewer pods per plant (McVetty et al., 1986), a constant number of seeds per pod (Thompson and Taylor, 1977; Ishag, 1973; Seitzer and Evans, 1973; Sprent et al., 1977), and a constant seed weight (Hodgson and Blackman, 1956; Day et al., 1979). Based on this, the increased yield seen at increasing seeding rates can be primarily attributed to an increase in plant population. The recommended seeding rate for faba beans in Alberta is 40 plants m^{-2} (Park and Lopetinsky, 1999). It may be necessary to use higher seeding rates to achieve optimal yields when drought conditions exist.

Each cultivar had a different strategy for building yield. Blitz and Snowbird, had large plant populations and many pods per plant. Earlibird had fairly large seeds and required large plant populations. Cresta had lower plant populations but a high level of tiller production and heavy seeds. Correlation results were obscured by the fact that individual yield components were measured on a per plant basis while yield and seed weight were measured on a per plot basis.

In conclusion, the yield and yield components for faba beans grown in north central Alberta responded to seeding rate in a similar manner as found in studies conducted in various parts of the world. Increased plant populations appear to be the key to increasing yield in faba beans grown in north central Alberta, particularly when drought conditions exist.

Table 3.1 Schedule of events for the experiment at Legal and Neerlandia in 2001 and 2002

	Herbicide Application	Yield Components	Desiccation	Harvest
Legal 2001	June 5	Aug 30	Sept 10	Sept 24
Legal 2002	June 10	Aug 23	Sept 5	Sept 23
Neerlandia 2001	June 8	Sept 10	Sept 6	Sept 17
Neerlandia 2002	June 7	Sept 2	Sept 12	Oct 1

Table 3.2 Significance of Year, Location, and Year x Location for YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg $seed^{-1}$)

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Year	NS	NS	**	**	**	**	**	**	**
Location	**	**	**	**	**	**	**	**	**
YxL	**	NS	NS	**	**	**	**	**	NS
Mean	3.5	40	1.6	24	16	2	2.0	3.0	562

*, ** Significant at the 0.05 and 0.01 levels respectively.

Y = year (2001, 2002), L = location (Legal, Neerlandia)

Table 3.3 Significance of seeding date, seeding rate, and cultivar for YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Legal and Neerlandia in 2001.

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Legal									
Date	NS	NS	NS	NS	NS	NS	NS	NS	**
Rate	NS	**	NS	NS	NS	NS	NS	NS	**
Cultivar	**	**	**	**	**	**	**	**	**
DxR	NS	**	NS	NS	NS	NS	NS	NS	NS
DxC	NS	NS	*	NS	NS	NS	NS	NS	**
RxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	*	NS
CV (%)	15	28	58	18	20	12	34	8	4
Neerlandia									
Date	**	*	NS	NS	NS	NS	NS	NS	**
Rate	NS	**	**	**	**	*	**	NS	NS
Cultivar	**	**	**	**	**	**	**	**	**
DxR	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxC	**	**	NS	NS	NS	NS	NS	**	**
RxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	9	20	45	22	24	9	30	5	4

*, ** Significant at the 0.05 and 0.01 levels respectively.

D = seeding date, R = seeding rate, C = cultivar, CV(%) = coefficient of variation

Table 3.4 Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Legal in 2001

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Seeding Date									
Early	2.3	43	1.6	22	15	1.8	8	4.0	580
Mid	2.4	31	1.6	26	18	1.9	11	4.0	578
Late	2.5	29	1.6	26	18	1.9	10	4.0	544
se	0.3	5.4	0.2	2.0	1.7	0.05	1.2	0.1	7.7
linear	NS	NS	NS	NS	NS	NS	*	NS	NS
deviate	NS	NS	NS	NS	NS	NS	NS	NS	**
Seeding Rate									
32	2.3	28	1.6	25	18	1.9	10	4.0	581
43	2.4	35	1.6	26	17	1.9	9	4.0	565
65	2.6	40	1.6	24	17	1.8	9	4.0	555
se	0.2	1.5	0.1	0.9	0.7	0.05	0.7	0.1	4.5
linear	NS	**	NS	NS	NS	NS	NS	NS	**
deviate	NS	*	NS	NS	NS	NS	NS	NS	NS
Cultivar									
Blitz	2.9 a	40 a	1.5 b	27 a	18 a	2.1 a	13 a	3.8 b	446 d
Earli	1.8 c	34 b	1.5 b	22 b	15 b	1.6 b	7 c	4.1 a	564 b
Cresta	2.2 b	30 b	1.8 a	23 b	17 a	1.7 b	7 c	4.0 a	729 a
Snow	2.7 a	34 b	1.5 b	28 a	18 a	2.1 a	11 b	4.1 a	529 c
se	0.1	2.2	0.1	1.1	0.8	0.05	0.7	0.1	5.8

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

Table 3.5 Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Neerlandia in 2001

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Seeding Date									
Early	4.3	46	1.8	33	25	2.3	19	3.2	592
Mid	5.0	39	1.9	36	26	2.3	21	3.2	535
Late	5.0	46	2.1	42	31	2.4	23	3.2	449
se	0.1	1.9	0.2	2.9	2.3	0.03	1.7	0.03	6.5
linear	**	*	NS	NS	NS	NS	NS	NS	**
deviate	*	NS	NS	*	*	NS	NS	NS	**
Seeding Rate									
32	4.6	34 c	2.2	42	32	2.4	25	3.2	531
43	4.8	41 b	1.9	35	26	2.3	19	3.2	526
65	4.9	56 a	1.7	33	24	2.3	18	3.2	520
Se	0.1	1.5	0.1	1.8	1.5	0.05	1.3	0.03	5.5
linear	NS	**	**	**	**	*	**	NS	NS
deviate	NS	NS	*	*	*	NS	*	NS	NS
Cultivar									
Blitz	4.8 b	48 a	1.9 b	40 a	29 a	2.7 a	28 a	3.0 b	402 d
Earlibird	4.1 c	43 b	1.8 b	32 b	24 b	2.1 b	16 c	3.3 a	539 b
Cresta	4.6 b	38 c	2.1 a	36 a	29 a	1.9 c	17 c	3.3 a	691 a
Snow	5.5 a	44 b	2.0 ab	40 a	27 a	2.6 a	22 b	3.3 a	470 c
se	0.1	2.0	0.1	1.9	1.5	0.05	1.4	0.04	4.5

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

Table 3.6 Significance of YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Legal and Neerlandia in 2002.

Source	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Legal									
Date	*	NS	*	**	**	NS	*	*	*
Rate	**	**	**	**	**	NS	**	NS	NS
Cultivar	**	**	**	**	**	NS	**	**	**
DxR	*	NS	NS	NS	NS	NS	NS	NS	NS
DxC	**	NS	*	NS	NS	NS	NS	NS	**
RxC	**	NS	*	NS	NS	NS	NS	NS	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	16	32	119	7	10	53	38	12	4
Neerlandia									
Date	NS	NS	*	*	**	NS	NS	**	**
Rate	**	**	**	**	**	NS	**	**	NS
Cultivar	**	**	**	**	*	**	**	**	**
DxR	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxC	**	NS	**	NS	NS	*	**	**	**
RxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxRxC	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8	27	56	18	20	11	22	7	4

*, ** Significant at the 0.05 and 0.01 levels respectively.

D = seeding date, R = seeding rate, C = cultivar, CV(%) = coefficient of variation

Table 3.7 Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Legal in 2002

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Seeding Date									
Early	1.2	38	1.1	21	13	1.8	4.8	2	588
Mid	1.7	36	1.3	23	14	1.7	6.0	3	615
Late	1.4	34	1.2	24	15	1.7	6.4	3	581
se	0.1	2.1	0.04	0.3	0.3	0.2	0.5	0.1	9.2
linear	*	NS	**	**	**	NS	NS	*	*
deviate	NS	NS	NS	**	**	NS	NS	*	*
Seeding Rate									
32	1.3	26	1.2	23	15	1.8	6.7	3	600
43	1.4	34	1.2	23	14	1.7	5.6	3	596
65	1.6	47	1.1	22	13	1.7	4.8	3	588
Se	0.1	2.1	0.04	0.4	0.3	0.2	0.5	0.1	5.1
linear	**	**	*	**	**	NS	**	NS	*
deviate	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar									
Blitz	1.6 a	38 ab	1.1 b	24 b	15 a	1.8 a	7.4 a	3 a	478 d
Earli	1.6 a	42 a	1.1 b	21 c	14 b	1.7 a	4.5 b	2 b	644 b
Crest	1.3 b	33 bc	1.3 a	20 d	13 c	1.5 a	4.6 b	3 a	679 a
Snow	1.2 b	31 c	1.1 b	25 a	15 a	1.8 a	6.4 a	3 a	578 c
se	0.1	2.7	0.05	0.4	0.3	0.2	0.5	0.1	6.2

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

Table 3.8 Seeding date, seeding rate and cultivar effects on YLD (yield; t ha^{-1}), PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), and TKW (seed weight; mg seed^{-1}) at Neerlandia in 2002

	YLD t ha^{-1}	PLNT plants m^{-2}	TIL plant^{-1}	NODES plant^{-1}	FNODES plant^{-1}	PPN pods node^{-1}	PPP plant^{-1}	SPP seeds pod^{-1}	TKW mg seed^{-1}
Seeding Date									
Early	5.8	46	1.83	17	13	1.8	15	3.0	639
Mid	5.8	40	1.40	17	12	1.9	17	3.2	553
Late	5.2	40	1.70	19	14	1.8	16	3.3	487
se	0.2	3.3	0.11	0.7	0.5	0.7	1.2	0.1	7.8
linear	NS	NS	**	NS	NS	NS	NS	*	**
deviate	*	NS	NS	**	**	NS	NS	*	**
Seeding Rate									
32	5.2	31	1.82	20	15	1.9	18	3.2	562
43	5.7	37	1.63	17	13	1.8	16	3.2	556
65	5.9	58	1.48	16	11	1.8	13	3.1	562
se	0.2	2.3	0.09	0.8	0.6	0.05	0.9	0.04	5.5
linear	**	**	**	**	**	NS	**	**	NS
deviate	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar									
Blitz	5.6 b	47 a	1.50 c	18.3 ab	12.8 ab	2.2 a	21 a	3.0 b	416 d
Earlibird	5.1 c	45 a	1.53 bc	15.6 c	11.6 b	1.5 d	11 d	3.0 b	639 b
Cresta	5.5 b	36 b	1.87 a	17.9 b	13.7 a	1.7 c	15 c	3.2 a	672 a
Snow	6.1 a	40 b	1.68 b	19.6 a	13.0 a	2.0 b	17 b	3.3 a	512 c
se	0.1	2.7	0.09	0.8	0.6	0.05	0.8	0.1	5.8

se = standard error, Linear = data has a linear trend, Deviate = data deviates from the linear trend, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively.

Table 3.9 Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; mg $seed^{-1}$), and YLD (yield; t ha^{-1}), in all site years.

All Cultivars, All Site Years								
	TIL	**NODES**	**FNODES**	**PPN**	**PPP**	**SPP**	**TKW**	**YIELD**
PLNT	NS	NS	NS	NS	NS	NS	NS	-0.09
TIL		0.71	0.69	NS	0.48	NS	NS	0.12
NODES			0.98	0.08	0.74	NS	-0.11	0.12
FNODES				NS	0.75	NS	-0.11	0.13
PPN					0.38	-0.27	0.09	NS
PPP						NS	-0.10	0.10
SPP							NS	NS
TKW								NS

Table 3.10 Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; mg $seed^{-1}$), and YLD (yield; t ha^{-1}), in all site years for the cultivar Earlibird

Earlibird, All Site Years								
	TIL	**NODES**	**FNODES**	**PPN**	**PPP**	**SPP**	**TKW**	**YIELD**
PLNT	-0.42	-0.40	-0.29	-0.38	-0.54	NS	0.67	0.39
TIL		0.35	0.60	0.27	0.59	0.36	NS	-0.52
NODES			0.76	NS	0.85	NS	NS	-0.64
FNODES				NS	0.70	0.21	NS	-0.68
PPN					0.19	-0.34	NS	-0.52
PPP						0.28	NS	-0.61
SPP							NS	0.19
TKW								NS

Table 3.11 Residual correlation coefficients for PLNT (plant population; plants m^{-2}), TIL (tillers per plant), NODES (nodes per plant), FNODES (flowering nodes per plant), PPN (pods per node), PPP (pods per plant), SPP (seeds per pod), TKW (seed weight; mg $seed^{-1}$), and YLD (yield; t ha^{-1}), in all site years for the cultivar Snowbird

Snowbird, All Site Years								
	TIL	**NODES**	**FNODES**	**PPN**	**PPP**	**SPP**	**TKW**	**YIELD**
PLNT	-0.19	0.29	0.23	0.54	-0.25	0.37	0.30	-0.24
TIL		0.83	0.87	-0.29	0.58	0.24	-0.73	-0.44
NODES			0.92	NS	0.70	0.29	-0.46	-0.37
FNODES				-0.33	0.75	0.23	-0.60	-0.35
PPN					-0.63	0.54	0.51	-0.25
PPP						-0.25	-0.42	NS
SPP							NS	-0.78
TKW								0.39

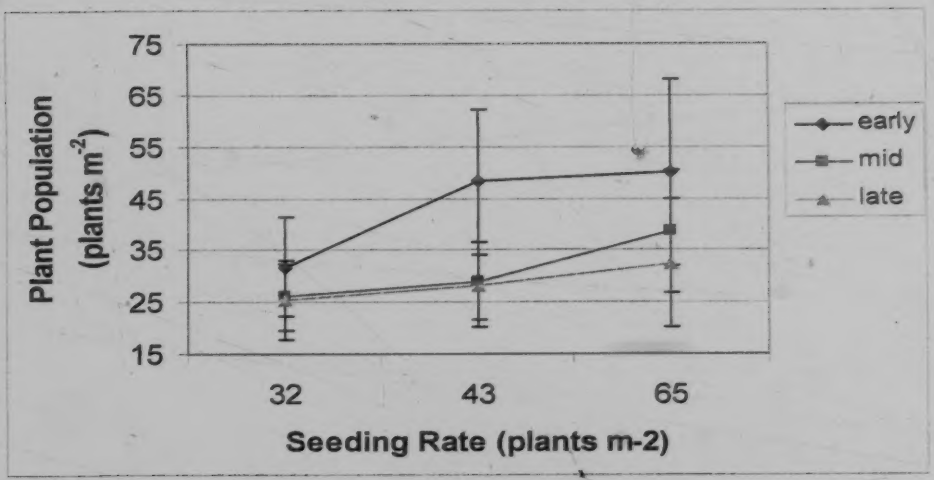

Figure 3.1: Effect of seeding rate on plant population at three seeding dates grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; P≤0.01)

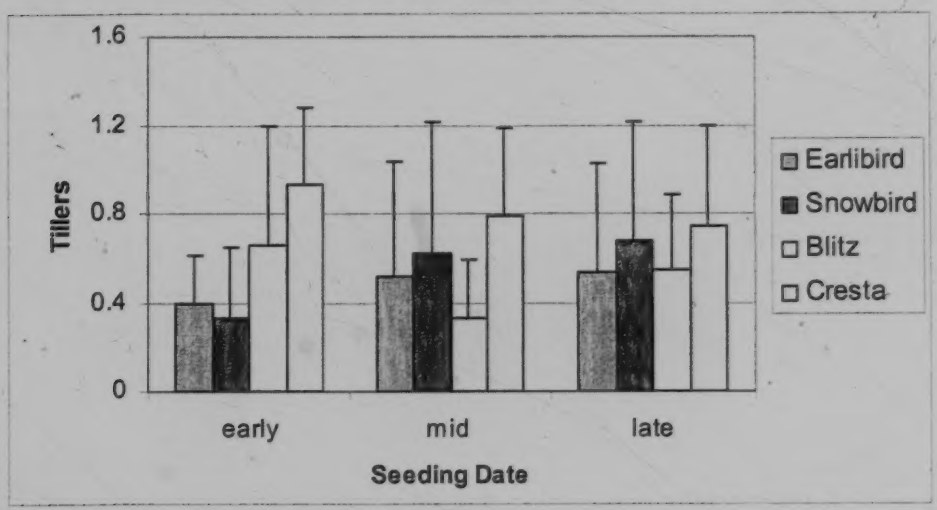

Figure 3.2: Effect of seeding date on tillers per plant for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05)

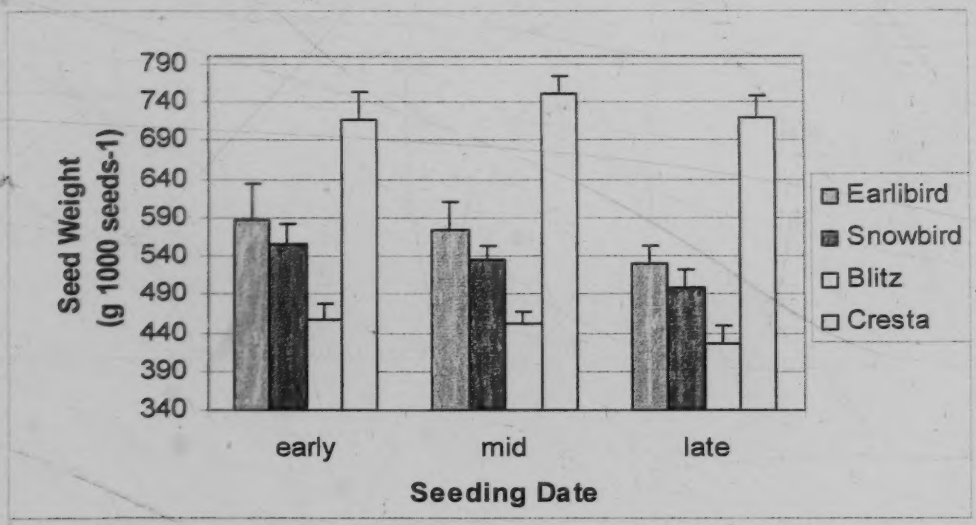

Figure 3.3: Effect of seeding date on seed weight for four faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01)

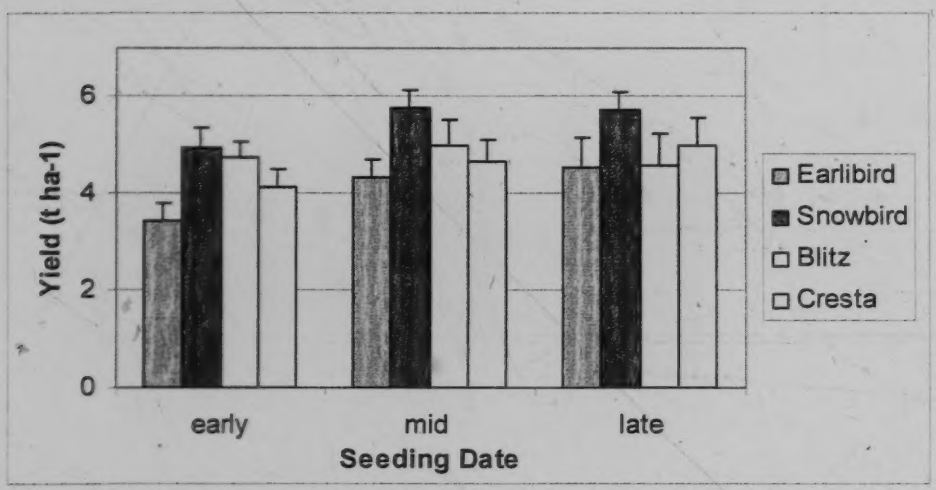

Figure 3.4: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

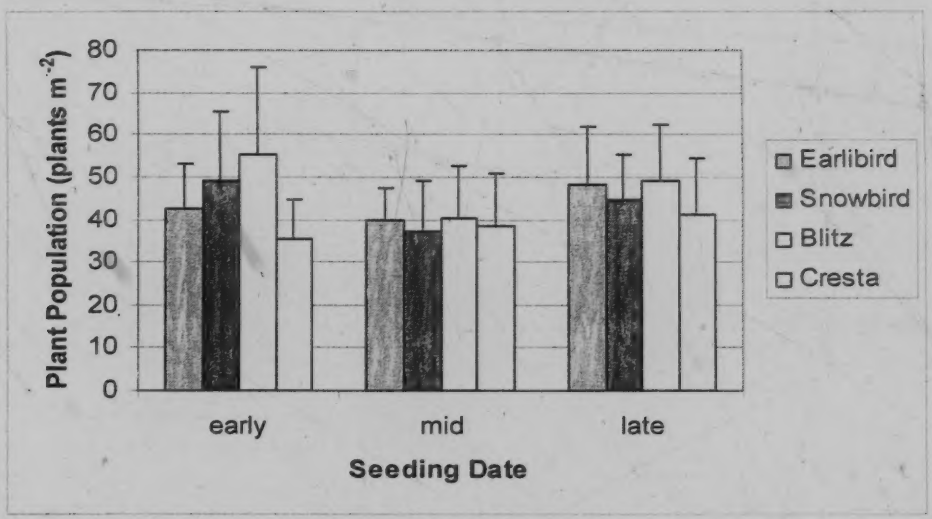

Figure 3.5: Effect of seeding date on plant population for four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

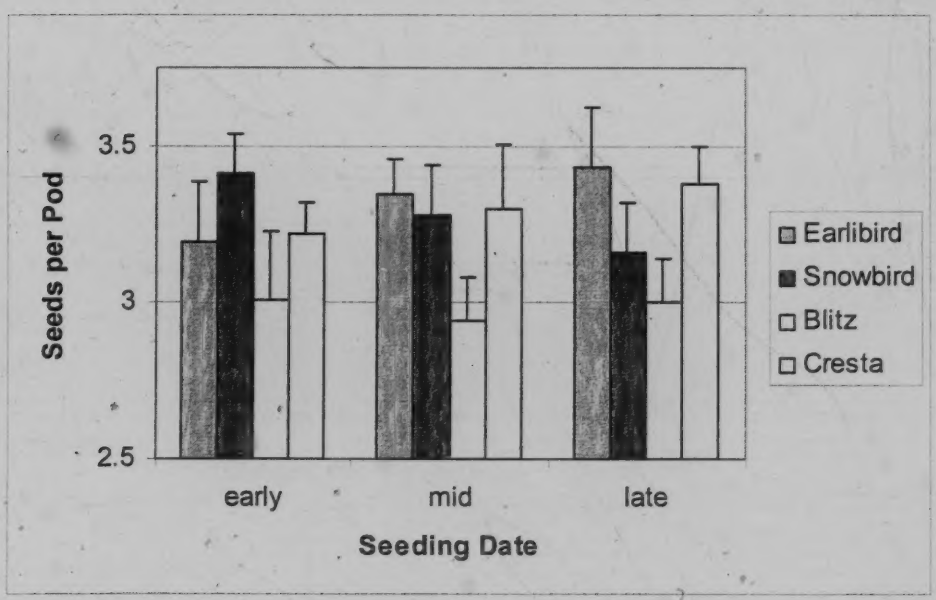

Figure 3.6: Effect of seeding date on seeds per pod of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

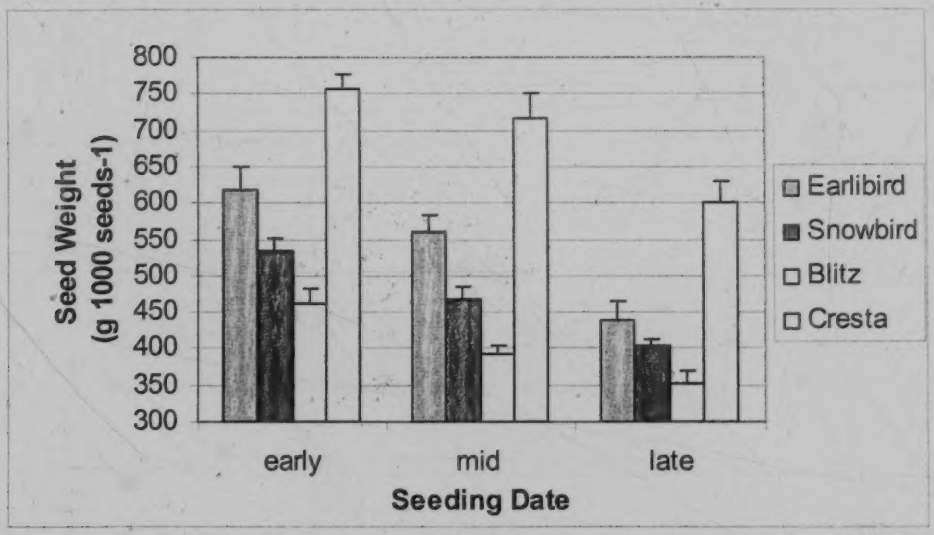

Figure 3.7: Effect of seeding date on seed weight of four faba bean cultivars grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

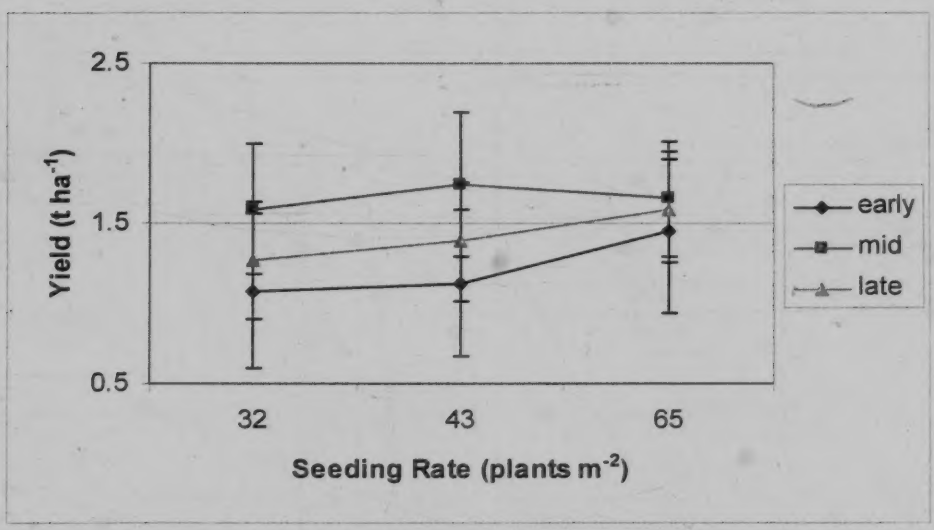

Figure 3.8: Effect of seeding rate on yield at three seeding dates grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x seeding rate interaction; P≤0.05).

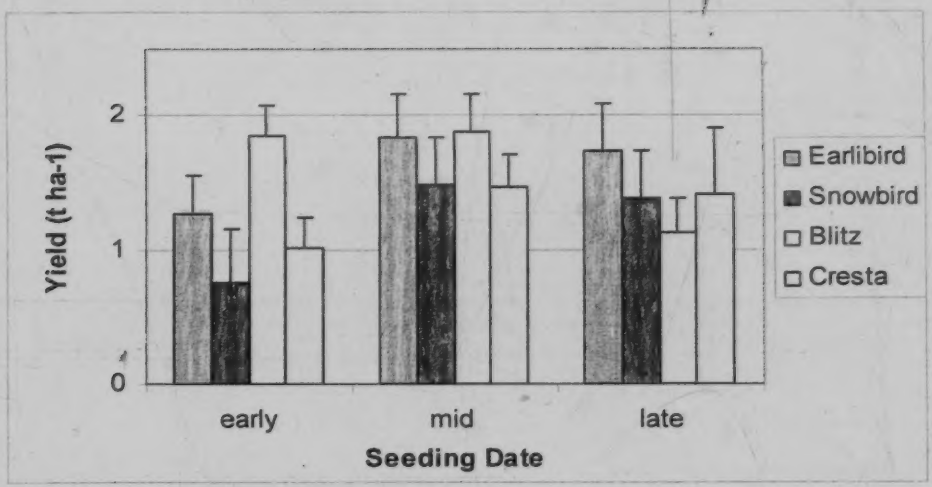

Figure 3.9: Effect of seeding date on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

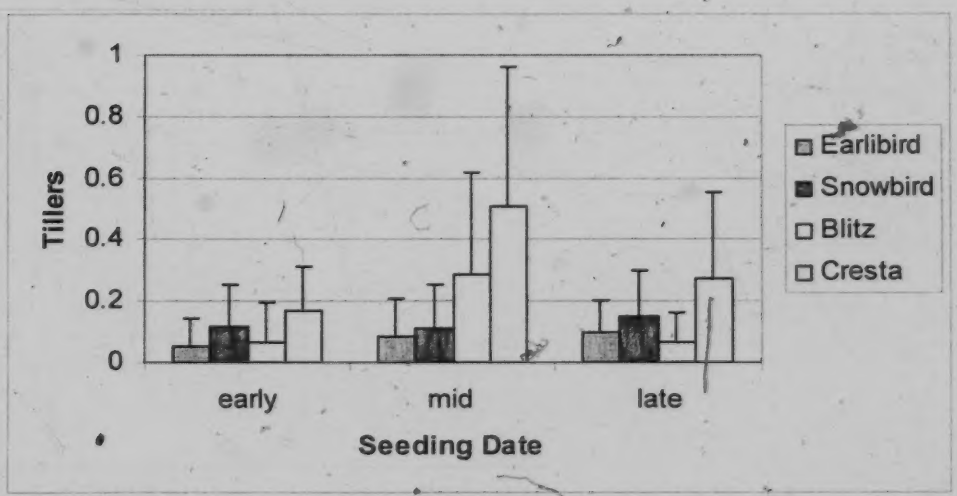

Figure 3.10: Effect of seeding date on tillers per plant for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05).

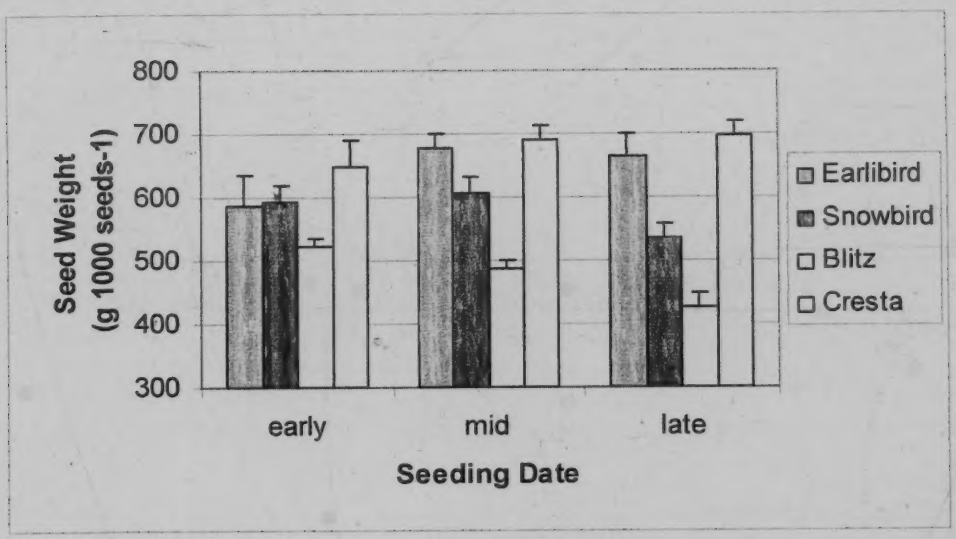

Figure 3.11: Effect of seeding date on seed weight for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

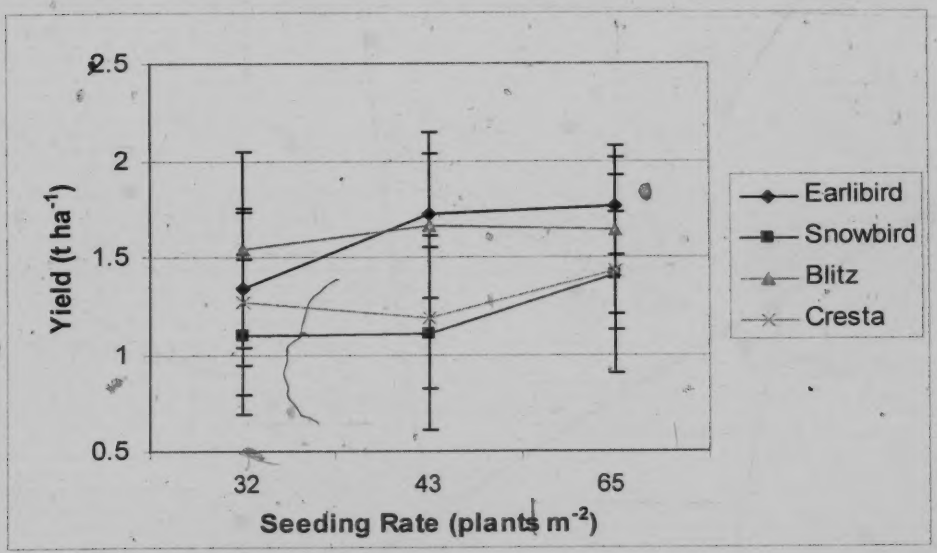

Figure 3.12: Effect of seeding rate on yield for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; P≤0.01).

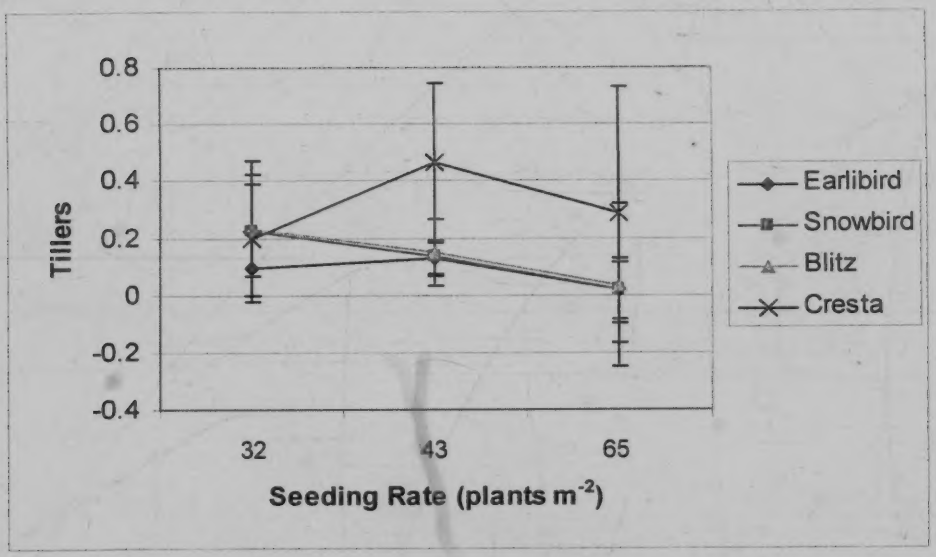

Figure 3.13: Effect of seeding rate on tillers per plant for four faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Seeding rate x cultivar interaction; P≤0.05).

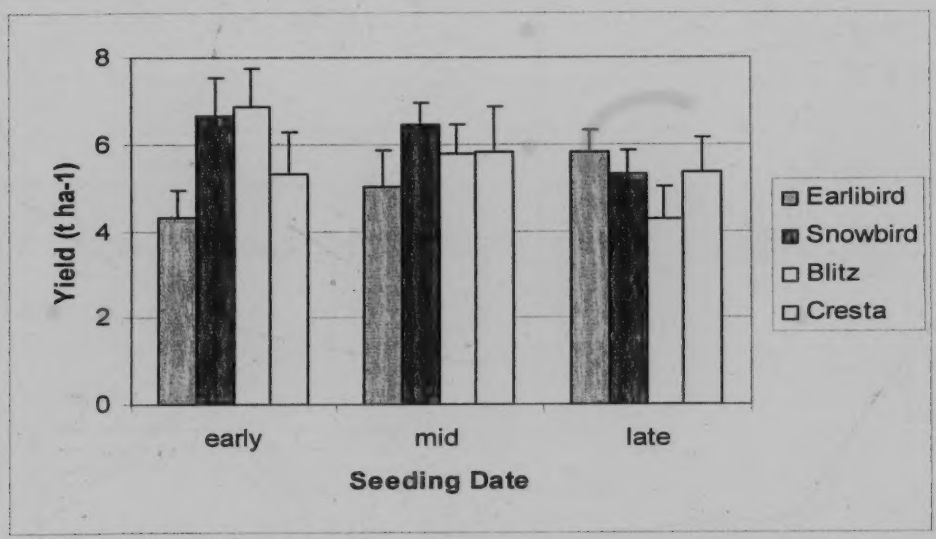

Figure 3.14: Effect of seeding date on yield for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

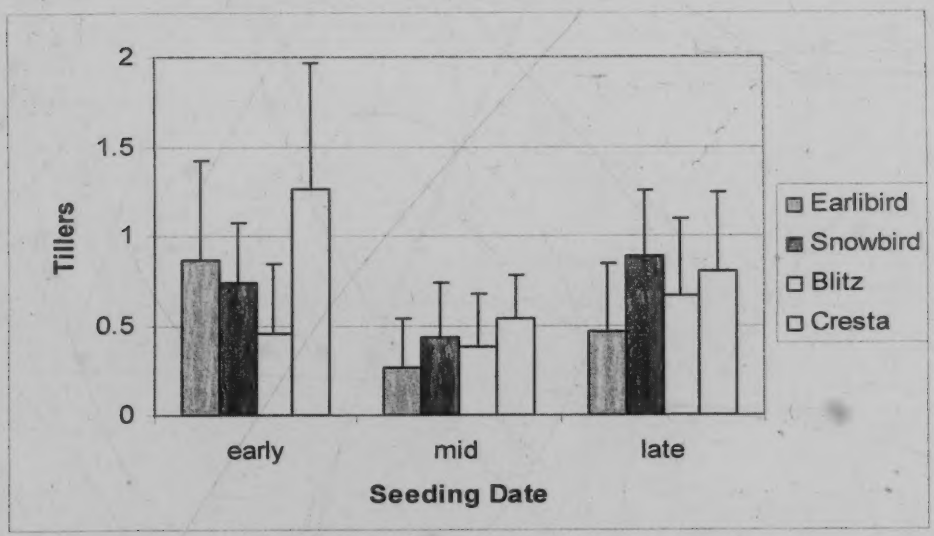

Figure 3.15: Effect of seeding date on tiller per plant for four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

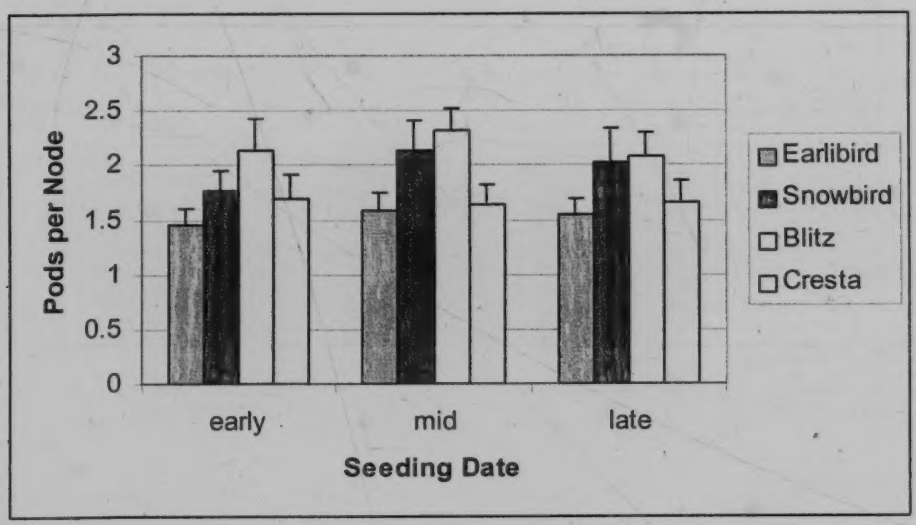

Figure 3.16: Effect of seeding date on pods per node of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.05).

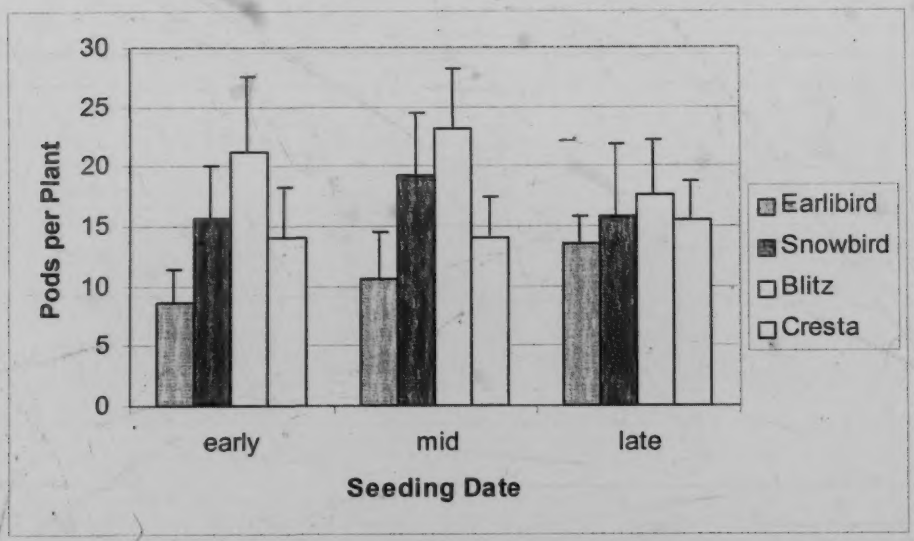

Figure 3.17: Effect of seeding date on pods per plant of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

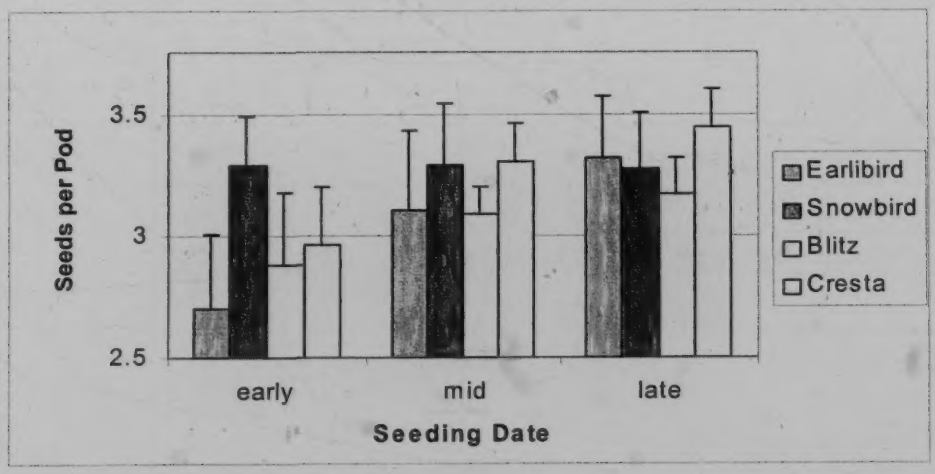

Figure 3.18: Effect of seeding date on seeds per pod of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

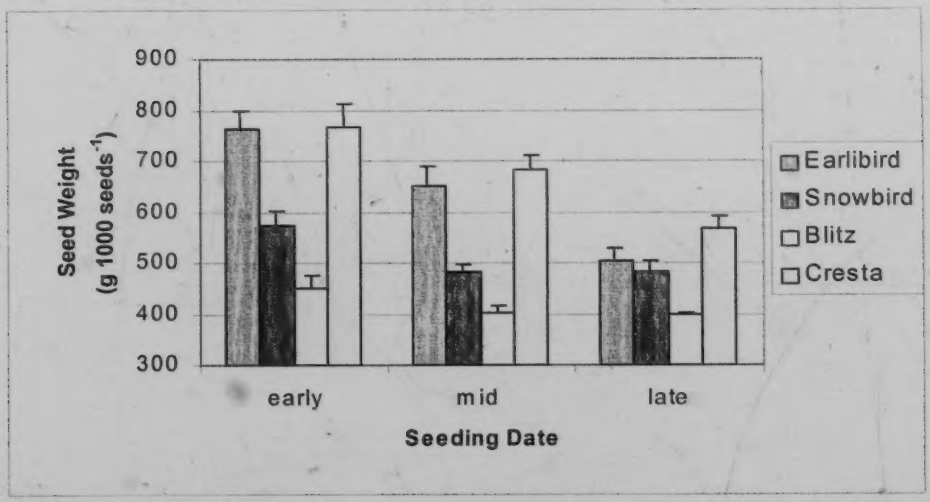

Figure 3.19: Effect of seeding date on seed weight of four faba bean cultivars grown at Neerlandia in 2002. Bars represent the standard deviation of the mean. (Seeding date x cultivar interaction; P≤0.01).

3.6 Literature Cited

Alberta Agriculture Weather Summary, 2001 and 2002. Electronic reference. Retrieved September 17, 2002. from http://www.agric.gov.ab.ca/climate

Ali, S., Calpas, J. and Bourne, J.B., eds., 2001. Crop Protection. Alberta Agriculture, Food and Rural Development Information Package Centre. Edmonton, Alberta, pp. 357-358.

Anderson, W.C., W.A. Haglund, G.W. Eaton and J. Fraser. 1986. Sequential yield component analysis of processing pea. HortScience. 21(1):103-105.

Ayoub, M., S. Guertin, S. Lussier, and D.L. Smith. 1994. Timing and level of nitrogen fertility effects on spring wheat yield in eastern Canada. Crop Sci. 34: 748-756.

Baldwin, B. 1980. Time of sowing – a major factor influencing the yields or *Vicia faba* in South Australia. FABIS Newsletter. 2:39.

Bowser, W.E., A.A. Kjearsgaard, T.W. Peters, and R.E. Wells. 1962. Soil Survey of Edmonton Sheet (83-H). University of Alberta.

Chapman, G.P. 1981. Genetic variation within *Vicia faba*. FABIS (June) p. 12.

Dantuma, G. and R. Thompson. 1983. Whole-crop physiology and yield components. In The Faba Bean (ed. P.D. Hebblethwaite), pp. 143-158. London : Butterworths.

Day, J.M., R.J. Roughley, and J.F. Witty. 1979. The effect of planting density, inorganic nitrogen fertilizer and supplementary carbon dioxide on yield of *Vicia faba* L. J. Agric. Sci., Camb. 93:629-633.

Edwards, D.A. and D.F. Beech. 1984. On the ordered development of plants. 3. Branching by the grain legume *Cyamopsis tetragonoloba* (guar). Annals of Botany. 54: 673-679.

Environment Canada. Canadian Climate Normals 1971-2000. Electronic reference. Retrieved January 28, 2003. from http://www.msc-smc.ec.gc.ca/climate/climate_normals/index_e.cfm

Farmzone Historical Accumulated Totals, 2001. Electronic reference. Retrieved June 20, 2002, from http://www.farmzone.com

Forbes, J.C. and R.D. Watson. 1994. Plants in agriculture. Cambridge University Press, Great Britain. pp.355.

Helsper, J.P.F.G., A. Van Norel, K. Burger-Meyer and J.M. Hoogendijk. 1994. Effect of the absence of condensed tannins in faba beans (*Vicia faba*) on resistance to foot rot, Ascochyta blight and chocolate spot. J. Agric. Sci., Camb. 123:349-355.

Hodgson, G.L. and G.E. Blackman. 1956. An analysis of the influence of plant density on the growth of *Vicia faba*. I. The influence of density of the pattern of development. J. Experimental Botany. 7:147-165.

Husain, M.M., G.D. Hill and J.N. Gallagher. 1988. The response of field beans (*Vicia faba* L.) to irrigation and sowing date 1.Yield and yield components. J. Agric. Sci. Camb. 111:221-232.

Ishag, H.M. 1973. Physiology of seed yield in field beans (*Vicia faba* L.). I. Yield and yield components. J. Agric. Sci., Camb. 80:181-189.

Kambal, A.E., 1969. Components of yield in field beans, *Vicia faba* L. J. Agric. Sci., Camb., 72: 359-363.

Kondra, Z.P. 1975. Effect of row spacing, seeding rate and date on seeding of faba beans. Can. J. Pl. Sci. 55:211-214.

Knott, C.M., A.J. Biddle and B.M. McKneown. 1994. PGRO Field Bean Handbook. Processors and Growers Research Organization, Peterborough, UK.

McVetty, P.B.E., L.E. Evans and J. Nugent-Rigby. 1986. Response of faba bean (*Vicia faba* L.) to seeding date and seeding rate. Can. J. Plant Sci. 66: 39-44.

Marcellos, H. and G.A. Constable. 1986. Effects of plant density and sowing date on grain yield of faba bean (*Vicia faba* L.) in Northern New South Wales. Aust. J. Exp. Agric. 26:493-6.

Martiniello, P. and A. Ciola. 1995. Dry matter and seed yield of Mediterranean annual legume species. Agronomy Journal. 87: 985-993.

Norwest Labs. 2002. Soil Test Recommendations for Faba Beans. Edmonton, AB.

Park, B. and K. Lopetinsky. 1999. Pulse Crops in Alberta. Alberta Agriculture, Food and Rural Development, Edmonton, AB. pp.123-140.

Picard, J. and P. Berthelem. 1981. A brief note on yield stability and 1000 grain weight in *Vicia faba*. FABIS 2:20.

Pilbeam, C.J., G. Duc, and P.D. Hebblethwaite. 1990. Effects of plant population on spring-sown field beans (*Vicia faba*) with different growth habits. Journal of Agricultural Science, Cambridge. 114: 19-33.

Pilbeam, C.J., P.D. Hebblethwaite, H.E. Ricketts and T.E. Nyongesa. 1991. Effects of plant population density on determinate and indeterminate forms of winter field beans (*Vicia faba*) 1. Yield and yield components. Journal of Agricultural Science, Cambridge. 116: 375-383.

Rowland, D.G. 1955. The problem of yield in field beans. Agric. Prog., 30:137-147.

Rowland, G.G. 1978. Effects of planting and swathing dates on yield, quality and other characteristics of faba beans (*Vicia faba*) in central Saskatchewan. Can. J. Plant Sci. 58:1-6.

SAS Institute. 1999. Version 8.1 ed. SAS Institute, Cary, N.C.

Seitzer, J.F. and L.E. Evans. 1973. Response of small seeded faba beans to seed rate and spacing. Can. J. Plant Sci. 53:279-283.

Spaner, D., A.G. Todd and D.B. McKenzie. 2000. The effect of seeding date, seeding rate and N fertilization on winter wheat yield and yield components in eastern Newfoundland. Can. J. Plant Sci. 80: 703-711.

Sprent, J.E., A.M. Bradford, and C. Norton. 1977. Seasonal growth patterns in field beans (*Vicia faba*) as affected by population density, shading and its relationship with soil moisture. J. Agric. Sci. (Camb.) 88:293-301.

Thompson, R. and H. Taylor. 1977. Yield components and cultivar, sowing date and density in field beans (*Vicia faba*). Ann. appl. Biol. 86:313-320.

Thompson, R. and H. Taylor. 1981. Factors limiting growth and yield of *Vicia faba*. pp. 34-45. In R. Thompson (ed.). Proceedings: EEC Seminar, *Vicia faba*: Physiology and Breeding, Wageningen Martinus Nijhoff and Commission of European Communities.

Wynnyk, A., J.D. Lindsay, and Wm. Odynsky. 1696. Soil Survey of the Whitecourt and Barrhead Area. University of Alberta.

Chapter 4
Effects of Harvest Management Tools on Faba Bean Yield

4.1 Introduction

The indeterminate growth habit of faba beans can create harvesting problems due to uneven ripening (Hebblethwaite, 1970). The bottom pods can be too dry to harvest and prone to shattering while upper pods remain too wet (Nash, 1978). Traditionally, swathing and desiccation have been used to overcome these harvesting difficulties. Swathing or desiccation is then followed by combining when pods are dry and black, the seed has a moisture content of 16 – 20 % and less than 10% of the stems are green (Knott et al., 1994).

Studies conducted in Manitoba (Betts and Morrison, 1980) found that swathing before the 25% black pod stage resulted in decreased yields, decreased seed size and shriveled, discolored seeds. In Saskatchewan, Rowland (1978) found that yield, seed protein content, seed size, and seedling fresh weight stabilized if plots were harvested when 30-40% of the lowest pods were black. He recommended swathing at this stage to attain highest yields, and acceptable seed quality, while minimizing shattering losses.

Chemical desiccation of faba beans, to accelerate plant and seed drying, is not always completely successful (Thompson and Taylor, 1982). Inadequate desiccant contact can occur when upper foliage intercepts the majority of the spray and prevents desiccant contact with the stem and pods. A dry period, following chemical application, improves desiccation efficacy. If precipitation follows

chemical application, seed moisture content may increase faster in desiccated than in undesiccated plants.

A commonly used desiccant is diquat (Reglone) applied at a rate of 0.4 – 0.6 kg/ha in medium water volumes of 55 L/ha (Betts and Morrison, 1980). Betts and Morrison (1980) found that diquat applied when at least 25% of the pods had turned black would not result in seed yield or quality losses. Desiccation before this stage could result in reduced yield and quality. Knott et al. (1994) recommends diquat applications at a much later desiccation stage when 90% of the pods are dry and black and most seed is dry.

Betts and Morrison (1980) compared dry down techniques of swathing versus chemical desiccation with diquat and found that there were fewer shriveled seeds with swathing. This may be due to a slower drydown of swathed plants. Diquat resulted in complete leaf kill in 2-4 days, whereas it took 5-10 days with swathing (Betts and Morrison, 1980). They concluded that assimilate movement to the seeds was brought to an abrupt halt by desiccation which resulted in the production of more shriveled seeds. Thus, desiccation prior to the 25% black pod stage was more detrimental to seed quality than early swathing before the 25% black pod stage.

Glyphosate is commonly used as a harvest management tool to dry down vegetative crop growth and late tillering that can interfere with harvest operations (Ali et al., 2001). Glyphosate is recommended for use in wheat, barley, canola, dry beans, flax, lentils, oats, peas, forages, and soybean. There has been little mention

in the literature of glyphosate being used as a dry down tool for faba beans. Knott et al. (1994) recommends that glyphosate be applied when faba bean pods are dry and black and the seed is hard. In most crops, glyphosate is applied 7-14 days prior to harvest to ensure the best weed control and maximize harvest benefits (Ali et al., 2001). Premature applications of glyphosate can result in yield losses. Glyphosate's efficacy is slowed under extremely cool, wet, and or cloudy conditions which delays crop dry down and harvest date. In addition, glyphosate cannot be used on crops intended for use as seed grain for future plantings.

The objective of this study was to determine the most effective chemical desiccation procedures to achieve optimal yield and quality of faba beans grown in north central Alberta.

4.2 Materials and Methods

4.2.1 Experimental Design

Plots of faba bean (*Vicia faba* L.) were seeded at Legal and Neerlandia, Alberta in 2001 and 2002 (Table 4.1). Soil at Legal is a Black Solodized Solonetz developed on till parent material (Bowser et al., 1962) and soil at Neerlandia is a Gleyed Orthic Black Chernozem developed on till and alluvial-lacustrine parent material (Wynnyk et al., 1969).

The experiment was a split-split plot design, with four blocks. Chemical dry down treatment formed the main plot, spray date the sub-plot and cultivar the sub-sub plot. Each sub-sub plot was 6.4 meters long and four rows wide with 20

cm row spacing. The three chemical dry down treatments were; an untreated control, diquat (Reglone Pro®), and glyphosate (Roundup®), each applied at 276 kPa with the hand wand of a CO_2 sprayer, at the recommended rate for field pea (Ali et al., 2001). Diquat was applied at 0.32 L ha^{-1} (200 g ai L^{-1}) and glyphosate at 0.4 L ha^{-1} (356 g ai L^{-1}) each with a water volume of 240 L ha^{-1}. There was an early and late spray date which corresponded to different physiological stages of the crop. The early spray date was at the 60 - 70% black pod stage and the late spray date was at the 90 – 95 % black pod stage (Table 4.2). These desiccation stages were selected to allow a maximum time for seed fill, and Knott et al. (1994), recommends diquat desiccation when 90% of the pods are black, and glyphosate desiccation when all pods are black. The two cultivars, Snowbird and Earlibird, each had a medium seed size. Snowbird is a medium maturing, tannin-free cultivar, while Earlibird is an early to medium maturing tannin-containing cultivar.

The target seeding rate was 43 plants m^{-2} (Appendix I, Table I-1). Seed samples of each cultivar were sent to 20/20 Seed Labs, Nisku for germination, vigor, and emergence testing and electrical conductivity (EC) analysis (Appendix I, Table I-2). In 2001, results from these tests were not received until May 24, so seeding rate calculations were based on a germination rate of 90% (Appendix I, Table I-1). In 2002, results were received prior to seeding and actual germination results were used to calculate seeding rates.

In 2001, due to dry soil conditions, the seeding depth was 7.6 cm to ensure that seed was placed into moist soil. Soil temperature at the time of seeding in

2001 was 11.5°C at Neerlandia and 13.3°C at Legal (15cm) (Appendix I, Table I-6). In 2002, there was excellent soil moisture at both locations. Seed was planted into -4.0°C soil at Neerlandia and 7.0°C soil at Legal. Seeding depth was 5 cm, at both locations. Plots were seeded with a double-disc press drill plot seeder into wheat stubble. At the time of seeding, 1.4 g $plot^{-1}$ of MicroBio Rhizogen Self-Stick Legume Inoculant for Faba beans, was mixed with the seed and placed in the furrow with the seed. The inoculant contained $1x10^9$ *Rhizobium leguminosarum* biovar *viceae* bacteria g^{-1}.

4.2.2 Soil Sampling

See Chapter 2, Section 2.2.2 Soil Sampling

4.2.3 Environmental Data

See Chapter 2, Section 2.2.3 Environmental Data

4.2.4 Weed Control and Plot Maintenance

In 2001, both locations were sprayed (Table 4.1) with a Poast Ultra and Pursuit tank mix at the recommended rate for field pea (Ali et al., 2001). Imazethapyr (Pursuit) at a rate of 17 mL ha^{-1} and 76 mL ha^{-1} of sethoxydim (Poast) were applied with a water volume of 112 L ha^{-1}. Subsequent hand weeding was done to control weed flushes.

Odyssey was used at both sites in 2002 to control weeds (Table 4.1). According to the recommendations for field pea, 6.8g ha^{-1} of imazamox + imazethapry (Odyssey) was applied with a water volume of 112 L ha^{-1} (Ali et al., 2001). Once again, hand weeding was necessary to control subsequent weed

flushes. In both years the area between blocks was rototilled to control weeds and allow for plot access.

4.2.5 Plant Populations

In 2002, cutworm damage was observed at the seedling stage therefore plant population counts were conducted three times in the spring (approximately 3, 4, and 4.5 weeks after seeding), and one week prior to harvest, to determine if cutworms caused decreases in plant populations (Appendix I, Table I-10). Plants were counted, at the center of each sub-sub plot, in two one-meter rows.

4.2.6 Chocolate Spot Assessments

Chocolate spot assessments were conducted in 2001 (Table 4.1). Leaves of three randomly selected plants per sub-sub plot were assessed on a nine-point scale. The nine-point scale used here (Appendix I, Table I-11) was devised based on the symptoms of chocolate spot infected faba beans, as described in Knott et al. (1994).

4.2.7 Leaf Drop Assessment

In 2001, leaf drop assessments were conducted (Table 4.1). Sub-sub plots were visually rated as having no, slight, moderate, or severe leaf drop (Appendix I, Table I-12). Leaf drop was not observed in 2002.

4.2.8 Plant Height Measurements

Plant height measurements were taken when most plants had finished flowering (Table 4.1). Two height measurements were made per sub-sub plot and plants were extended and measured at the tip of the tallest leaf.

4.2.9 Late Season Stem Disease

In 2002, at Legal, dead plants were found in the plots (Plate 4-1). Samples of the dead plants were taken to determine the pathogen responsible for infection and subsequent death. Stem sections (0.5 – 1cm) were taken and placed in a moist, sterile petri dish. Petri dishes were incubated for 3 days and resulting fungal growth was examined to determine the infection pathogen.

4.2.10 Physiological Stage at Harvest

The physiological stage, at the time of harvest, was assessed to determine the ability of the chemical desiccant to hasten maturity (Table 4.1). At the time of assessment, all pods were black so the physiological stage was assessed as the percent black stems existing in the sub-sub plot. If a sub-sub plot had a low percentage of black stems, this indicated that maturity had not been hastened.

4.2.11 Seed Yield and Seed Weight

Sub-sub plots were harvested using a Wintersteiger plot combine (Table 4.1). Harvested seed was dried for 24 to 48 hours, depending on sample moisture, at 30-33°C in a forced air drier. Dried samples were weighed and seed weights (1000 kwt) were determined.

In 2002, seed shattering occurred. In order to estimate these losses, a piece of legal sized paper (0.08 m^2) was placed over the middle two rows, at the center of the harvested sub-sub plot. Seeds lying within this area were counted. To determine the lost yield, the number of seeds lost per sub-sub plot was multiplied by the sub-sub plot's 1000 kwt and this value was added to the sub-sub plot's yield.

4.2.12 Statistical Analysis

All agronomic characteristics were analyzed with analysis of variance. Statistical analysis was completed using Statistical Analysis System (SAS Institute, 1999). A Tukey's test was used to separate the means when treatment effects were significant ($P \leq 0.05$). Leaf drop and chocolate spot were used as covariables to adjust for effects of leaf area damage. When the covariable was significant, adjusted means and adjusted standard errors were presented.

4.3 Results and Discussion

4.3.1 Environmental Data

See Chapter 2, Section 2.3.1 Environmental Data

4.3.2 Plant Populations

There were minor differences between the spring and final plant population counts conducted in 2002. At Neerlandia and Legal, spring counts had average plant populations of 16 plants m^{-2}, whereas the pre-harvest counts had average plant populations of 17 plants m^{-2} (data not included). Thus, there was not significant cutworm damage over the growing season. Plant populations were less than half of the target plant population of 43 plants m^{-2}.

4.3.3 Chocolate Spot and Leaf Drop

Chocolate spot infection and leaf drop were only measured in 2001 and they were significantly different between locations ($P \leq 0.05$) (Table 4.3). Chocolate spot infection and leaf drop were more severe at Neerlandia (5.4 and 2.5 respectively)

than at Legal (4.6 and 2.0 respectively) (data not included). There were no significant differences between cultivars for chocolate spot infection ($P \geq 0.05$) (Table 4.4). Leaf drop was significantly different for each cultivar ($P \leq 0.01$) (Table 4.4) with Earlibird (2.5) having more severe leaf drop than Snowbird (2.0) (Table 4.5).

Leaf drop removed leaf area and chocolate spot infection damaged leaf tissue in 2001. The smaller leaf area was expected to hinder glyphosate uptake as there was reduced surface area for desiccant contact with the plant. Leaf tissue damage by chocolate spot may have interfered with glyphosate movement into the plants.

The reduced leaf area may have improved the efficacy of diquat. Diquat is considered a contact herbicide (Summers, 1980). A potential problem with using diquat as a desiccant in faba beans is inadequate desiccant contact, which can occur when upper foliage intercepts the majority of the spray and prevents direct desiccant contact with the stem and pods (Thompson and Taylor, 1982). With fewer leaves on the plants, diquat may have been more effective.

Leaf drop was a significant co-variable for physiological stage at harvest and yield at Legal in 2001 ($P \leq 0.05$) (Table 4.4). This indicates that leaf drop interfered with chemical desiccation and as a result, physiological stage at harvest and yield were affected. Chocolate spot was not a significant co-variable ($P \geq 0.05$) (Table 4.4). It appears that leaf drop, in some instances, interfered with the

chemical desiccation treatments, but moderate levels of chocolate spot infection did not.

4.3.4 Plant Height Measurements

Plant heights were significantly different between years and locations ($P \leq 0.01$) (Table 4.3). Plants were taller in 2001 (59cm) than in 2002 (45cm), and taller at Neerlandia (66cm) than at Legal (38cm) (data not included). Plant heights differed with cultivar ($P \leq 0.01$) (Table 4.4) with Snowbird (55cm) being taller than Earlibird (48cm) (Table 4.5).

4.3.5 Late Season Stem Disease

Two fungal pathogens were found on Earlibird plants from Legal in 2002. The pathogens were identified as *Fusarium* sp. and *Verticillium* sp., which are common vascular wilting fungi. Between 10 and 15% of Earlibird sub-sub plots suffered from the fungal infection (data not included). Snowbird did not show any late season stem disease.

4.3.6 Physiological Stage at Harvest

Physiological stage at harvest was significantly affected by year ($P \leq 0.05$), location ($P \leq 0.01$), and year x location ($P \leq 0.01$) (Table 4.3). These differences were the result of the differing growing conditions in each site year.

Chemical desiccation treatment significantly affected physiological stage at harvest in all site years ($P \leq 0.01$) (Table 4.4). The diquat and glyphosate treatments were at a more advanced physiological stage compared to the control treatment (Table 4.5, Plate 4-3). However, differences in physiological stage at harvest

between the control and glyphosate treatments were not always significant. Faba beans which were not desiccated had 5 to 69% black stems, at the time of harvest depending on the site year (Table 4.5). The presence of a high percentage of green stems could create harvesting difficulties.

Glyphosate (70% black stems; average of four site years) was less effective at hastening maturity compared to diquat (92% black stems; average of four site years). Neither desiccant resulted in yield or seed weight reductions, although diquat hastened maturity more rapidly than glyphosate. Nevertheless, glyphosate may be useful as a desiccant if producers are attempting to control perennial weeds (Ali et al., 2001). However, diquat has the advantage of producing viable seed, whereas glyphosate applications will kill seeds making them unsuitable as a seed source for future faba bean propagation.

Desiccation application date affected physiological stage at maturity only at Legal in 2001 ($P \leq 0.05$) (Table 4.4). Faba beans that were desiccated early were at a more advanced physiological stage (72% black stems), at the time of harvest, compared to faba beans that were desiccated late (57% black stems) (Table 4.5). Differences may not have been seen in the other site years as the two desiccant application dates may have been too close together.

There were significant differences in physiological stage at harvest between cultivars in 2002 at both locations (Legal, $P \leq 0.01$; Neerlandia, $P \leq 0.05$) (Table 4.4). At Legal, Earlibird (59% black stems) was at a more advanced physiological stage at harvest compared to Snowbird (37% black stems) (Table 4.5). This was

expected, as Earlibird naturally matures sooner than Snowbird (Anonymous, 2002; Anonymous, 2003). At Neerlandia in 2002, small differences existed between the cultivars however they were not biologically significant. On average, undesiccated Earlibird plots contained 35% black stems (average of four site years) and undesiccated Snowbird plots contained 33% black stems (average of four site years) (data not included). For both cultivars, chemical desiccation helped to enhance drydown and ease harvestability.

The chemical desiccant treatment x cultivar interaction was significant (Table 4.4) at Legal in 2001 ($P \leq 0.05$) (Figure 4.1) and 2002 ($P \leq 0.01$) (Figure 4.2). In both years, Earlibird was at a more advanced physiological stage compared to Snowbird in the control and glyphosate treatments. This was observed with the glyphosate treatment because glyphosate is a slow acting desiccant (Corbett et al., 1984) therefore allowing natural maturity differences to be observed between cultivars. When Earlibird and Snowbird were desiccated with diquat, their physiological stages at harvest were similar. No differences in physiological stage were observed with diquat due to its ability to rapidly kill a plant (Summers, 1980), regardless of the cultivar's natural maturation process (Plate 4-2).

The desiccant application date x cultivar interaction was significant only at Legal in 2001 ($P \leq 0.01$) (Table 4.4). Physiological stages were similar for faba bean cultivars desiccated at the early desiccation date (Figure 4.3). When desiccation took place at the late application date, Earlibird was slightly more

mature than Snowbird. This was expected due to Earlibird's rapid natural maturation process (Anonymous, 2002).

Earlibird plots sprayed with diquat at Neerlandia in 2002 had regrowth of new tillers from the base of the plants. Diquat does not damage protected meristematic tissue at the base of the plant, because the active ingredient is immediately deactivated on contact with the soil due to cation exchange with clay particles, which binds the active ingredient firmly to the soil particles (Summers, 1980). Earlibird was therefore able to regrow from protected meristematic tissue following desiccation with diquat. This only occurred at Neerlandia in 2002, as good growing conditions were present at this site following desiccation.

4.3.7 Seed Yield

Year, location, and year x location were significant for yield ($P \leq 0.01$) (Table 4.3). Yields were similar at Neerlandia in 2001 and in 2002 (4.9 t ha^{-1}), however, at Legal yields were higher in 2001 (2.2 t ha^{-1}) than in 2002 (0.7 t ha^{-1}) (data not included). These differences were a result of different growing conditions in each site year.

There were no significant yield differences between the diquat, glyphosate, or control treatments ($P \geq 0.05$) (Table 4.4). Yields were not significantly decreased by desiccant treatments compared to the control.

Early desiccant application (0.7 t ha^{-1}) resulted in significantly lower yields ($P \leq 0.05$) (Table 4.4) compared to the late desiccant application (0.8 t ha^{-1}) (Table 4.5) at Legal in 2002. The difference, although significant, was small (0.1 t ha^{-1}),

and may be significant due to the low yields at this site. Yields were not significantly affected by desiccant application date in the three other site years ($P \geq 0.05$) (Table 4.4). This indicates that desiccants can be applied at either the early (60-70% black pod stage) or late stage (90-95% black pod stage) and yields will not be reduced which is in agreement with the findings of Betts and Morrison (1980) and Rowland (1978).

At Neerlandia in 2001, the chemical desiccant treatment x desiccant application date was significant ($P \leq 0.05$) (Table 4.4). Yields of the control treatments were similar at both desiccation dates, as expected, but yields of the diquat and glyphosate treatments differed depending on desiccant application date (Figure 4.4). Faba beans desiccated with glyphosate showed a slight decrease in yield when glyphosate was applied at the late desiccation stage compared to the early desiccation stage (Neerlandia, 2001). This was unexpected. One would expect that applying glyphosate early (60 – 70% black pods stage), within 40 to 65 days after fertilization (in mid to late August), while seeds are still filling (Grzesiuk and Sojka, 1961), would reduce yield. However, differences were small (0.1 t ha^{-1}). Faba beans desiccated with diquat at the early stage yielded slightly less than faba beans desiccated with diquat at the late stage (Figure 4.4). Plants desiccated at the early stage may not have fully mature seeds (Grzesiuk and Sojka, 1961) therefore, desiccating with a quick acting desiccant such as diquat may have pre-maturely ceased seed fill of the immature seeds. In 1980, Betts and Morrison found that diquat caused complete leaf kill in 2-4 days. They concluded that

assimilate movement to the seeds was abruptly halted by diquat desiccation, which resulted in the production of more shriveled seeds and reduced yields.

Cultivars had different yields in all site years ($P \leq 0.01$) (Table 4.4) with the cultivar Snowbird having higher yields in all site years (Table 4.5).

At Legal in 2001, yields of the cultivars followed significantly different trends depending on desiccant application date ($P \leq 0.05$) (Table 4.4). Earlibird had a relatively constant yield regardless of desiccant application date but Snowbird had better yields when desiccants were applied at the late stage (Figure 4.5). Earlibird is a very determinate cultivar and the seeds may have been more mature at the time of the early desiccant application, compared to the Snowbird seeds (Anonymous, 2002; Anonymous, 2003). Desiccant application at the early stage may have prematurely ceased Snowbird seed fill, thereby resulting in reduced yields. However, this trend only exists at one site year.

4.3.8 Seed Weight and Seed Shatter

Seed weight was significantly affected by year ($P \leq 0.05$) (Table 4.3), with seeds being significantly heavier in 2002 (631mg seed^{-1}) than in 2001 (605mg seed^{-1}) (data not included). Cultivars had different seed weights ($P \leq 0.01$) (Table 4.4) with Earlibird seeds (664 mg seed^{-1}) being significantly heavier than Snowbird seeds (572 mg seed^{-1}) (Table 4.5). Seed weight was not significantly affected by any other treatment ($P \geq 0.05$) (Table 4.4).

Chemical desiccant application was expected to cease seed fill of immature seeds thereby resulting in lighter seeds compared to the control. In these

experiments, chemical desiccants were effective at hastening maturity without decreasing seed weight or yield, when applied at the early and late spray dates. Therefore, chemical desiccation was able to improve harvestability without sacrificing yield or seed weight.

Chemical desiccant treatment and desiccant application date did not significantly affect seed shatter when glyphosate or diquat were applied at the 60-70% or 90-95% black pod stages at either location ($P \geq 0.05$) (results not included). At Legal in 2002, seed shatter differed significantly with cultivar ($P \leq 0.01$) where Earlibird had 6 times more seed shattering that Snowbird (results not included). At Neerlandia in 2002, seed shatter did not differ with cultivar ($P \geq 0.05$) but Earlibird had slightly more seed shattering than Snowbird (results not included). The seed shattering problems are likely due to Earlibird's more rapid natural maturity and they could have been avoided with earlier harvesting.

4.4 Conclusions

In this study, glyphosate and diquat desiccation hastened physiological maturity compared to the control. The high levels of green stems remaining in the untreated control plots could create harvesting difficulties which indicates that desiccants are necessary for faba bean production in north central Alberta. In comparing the two chemical desiccants, diquat was able to advance physiological maturity more rapidly than glyphosate. Physiological stage at the time of harvest

was the same regardless of early (60-70% black pods) or late (90-95% black pods) desiccant application.

Glyphosate may be useful as a desiccant, if producers are also attempting to control perennial weeds (Ali et al., 2001). However, diquat has the advantage of producing viable seed, whereas glyphosate applications will kill the seeds making them unsuitable as a seed source for future faba bean propagation.

Desiccant applications of diquat and glyphosate did not reduce seed size or yields compared to the untreated control at either the early or late desiccant application date. This indicates that chemical desiccation as early as the 60-70% black pod stage was able to advance physiological maturity and improve harvestability without sacrificing seed weight or yield.

Based on the findings of this study, chemical desiccation of faba beans in north central Alberta is necessary to hasten physiological maturity and reduce the percent of green stems in the crop. Diquat was more effective at hastening maturity than glyphosate. Neither chemical desiccant reduced seed size or yield when they were applied at the 60-70% black pod stage or later. Thus, it is recommended that diquat be applied at the 60-70% black pod stage to ease harvestability of faba beans grown in north central Alberta.

Table 4.1 Schedule of events for the desiccation experiments at Legal and Neerlandia in 2001 and 2002

	SD	HERB	CHC	LEAF	HGT	PHYS	HARV
Legal 2001	April 25	June 5	August 21	August 21	Aug 21	Sept 17	Sept 24
Legal 2002	May 8	June 10	n/a	n/a	Aug 17	Sept 23	Sept 23
Neerlandia 2001	April 25	June 8	August 22	August 22	Aug 14	Sept 10	Sept 17
Neerlandia 2002	May 8	June 7	n/a	n/a	Aug 27	October 1	October 1

SD = seeding date, HERB = herbicide applications, CHC = chocolate spot assessment, LEAF = leaf drop assessment, HGT = plant height measurements, PHYS = physiological stage at the time of harvest assessment, HARV = harvest.

Table 4.2 Desiccation application dates at Neerlandia and Legal in 2001 and 2002

Desiccation Stage	Desiccation Date			
	Legal 2001	**Legal 2002**	**Neerlandia 2001**	**Neerlandia 2002**
Early[1]	August 21	August 26	August 29	August 31
Late[2]	August 29	August 31	September 6	September 4

[1] Early desiccation corresponds to the physiological stage at which 60-70% of the pods are black

[2] Late desiccation corresponds to the physiological stage at which 90-95% of the pods are black

Table 4.3 Significance of Year, Location, and Year x Location for chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; mg seed^{-1}).

	All Locations					
	CHC 1-9	**HGT** cm	**LEAF** 0-3	**PHYS** % black stems	**YLD** t ha^{-1}	**KWT** mg seed^{-1}
Year		**		*	**	*
Location	*	**	*	**	**	NS
Year x Location		NS		**	**	NS
Mean	5	52	2.3	65	3.1	618
CV (%)	12	6	25	11	11	4

*, ** Significant at the 0.05 and 0.01 levels respectively.
CV(%) = coefficient of variation

Table 4.4 Significance of Chemical desiccation treatment, Desiccation Application Date, and Cultivar for chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; mg seed^{-1}).

Source	CHC 1-9	HGT cm	LEAF 0-3	PHYS % black stems				YLD t ha^{-1}				KWT mg seed^{-1}
				Legal 2001	Legal 2002	Neer 2001	Neer 2002	Legal 2001	Legal 2002	Neer 2001	Neer 2002	
Main Effects												
Chem				**	**	**	**	NS	NS	NS	NS	NS
Date				*	NS	NS	NS	NS	*	NS	NS	NS
Cultivar	NS	**	**	NS	**	NS	*	**	**	**	**	**
Interactions												
Chem x Date				NS	NS	NS	NS	NS	NS	*	NS	NS
Chem x Cultivar				*	**	NS	NS	NS	NS	NS	NS	NS
Date x Cultivar				**	NS	NS	NS	*	NS	NS	NS	NS
ChemxDatexCultivar				NS	NS	NS	NS	NS	NS	NS	NS	NS
Co-Variables												
CHC co-var				NS		NS		NS		NS		
LEAF co-var				*		NS		*		NS		
Mean	5	52	2.3	64	48	58	89	2.2	0.7	4.9	4.8	618
CV (%)	12	6	25	7	15	18	5	11	20	10	9	4

NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively, CV% = coefficient of variation.

Table 4.5 Chemical desiccation treatment, Desiccation Application Date, and Cultivar effects on chocolate spot infection (CHC; 1-9), height (HGT; cm), premature leaf drop severity (LEAF; 0-3), physiological stage at harvest (PHYS; percent black stems), yield (YLD; t ha^{-1}), and seed weight (KWT; mg seed^{-1}).

Source	CHC 1-9	HGT cm	LEAF 0-3	PHYS[1] % black stems				YLD[1] t ha^{-1}				KWT mg seed^{-1}
				Legal 2001	Legal 2002	Neer 2001	Neer 2002	Legal 2001	Legal 2002	Neer 2001	Neer 2002	
Chemical Desiccant Treatment												
Control				15 b	5 b	42 b	69 b	2.3 a	0.8 a	5.0 a	5.0 a	623 a
Diquat				95 a	100 a	73 a	100 a	2.0 a	0.7 a	5.0 a	4.7 a	610 a
Glyphosate				83 a	40 b	57 b	99 a	2.1 a	0.7 a	4.7 a	4.8 a	622 a
se				6.4	2.2	5.0	6.6	0.1	0.1	0.2	0.3	5.5
Desiccant Application Date												
Early				72 a	47 a	58 a	90 a	2.1 a	0.7 b	4.9 a	4.8 a	618 a
Late				57 b	49 a	57 a	89 a	2.2 a	0.8 a	4.9 a	4.9 a	618 a
se				5.4	1.9	3.8	1.3	0.1	0.04	0.1	0.2	3.2
Cultivar												
Earlibird	5.1 a	48 b	2.5 a	65 a	59 a	55 a	87 b	1.9 b	0.6 b	4.1 b	3.8 b	664 a
Snowbird	4.9 a	55 a	2.0 b	64 a	37 b	60 a	91 a	2.4 a	0.8 a	5.6 a	5.9 a	572 b
se	0.1	0.4	0.1	1.4	2.1	3.1	1.5	0.1	0.04	0.1	0.1	3.3

se = standard error, NS = non-significant, *,** significant at the 0.05 and 0.01 levels respectively. All means separated with a Tukey's test.

[1] se for these traits is the adjusted se

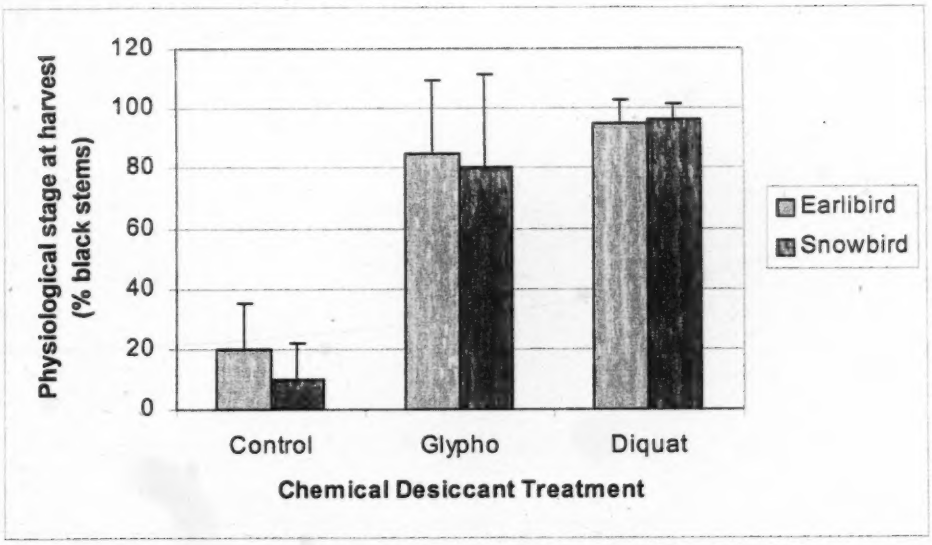

Figure 4.1: Effect of chemical desiccant treatment on physiological stage at harvest for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Chemical desiccant x cultivar interaction; $P \leq 0.05$).

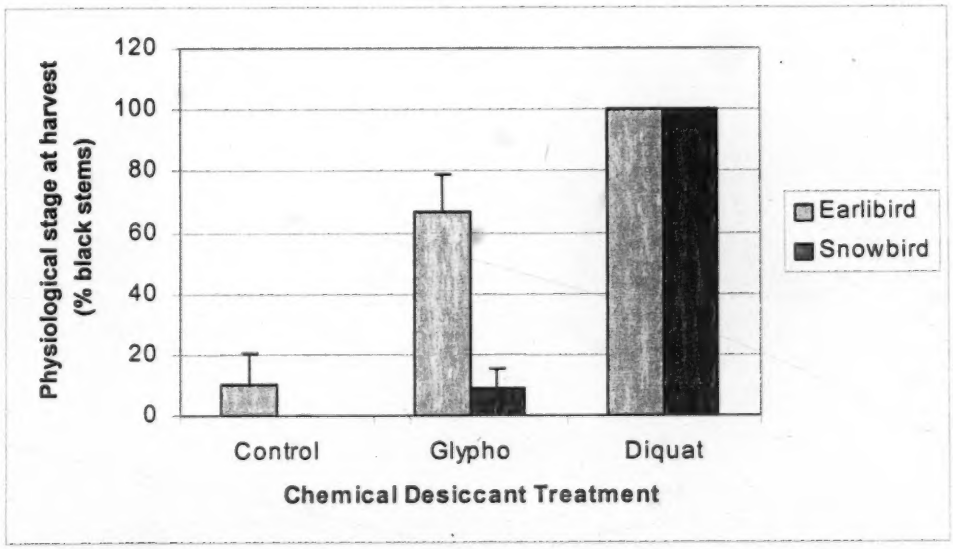

Figure 4.2: Effect of chemical desiccant treatment on physiological stage at harvest for two faba bean cultivars grown at Legal in 2002. Bars represent the standard deviation of the mean. (Chemical desiccant x cultivar interaction; $P \leq 0.01$).

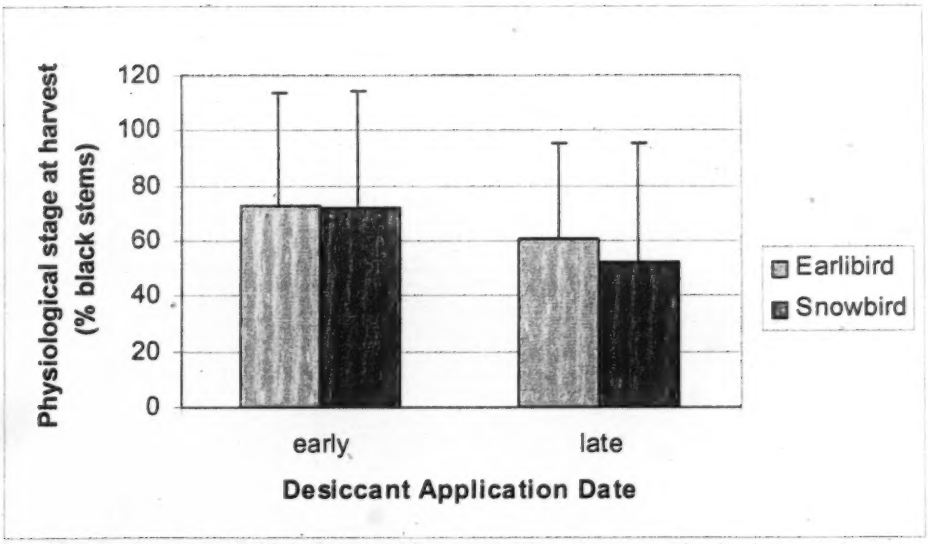

Figure 4.3: Effect of desiccant application date on physiological stage at harvest for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.01).

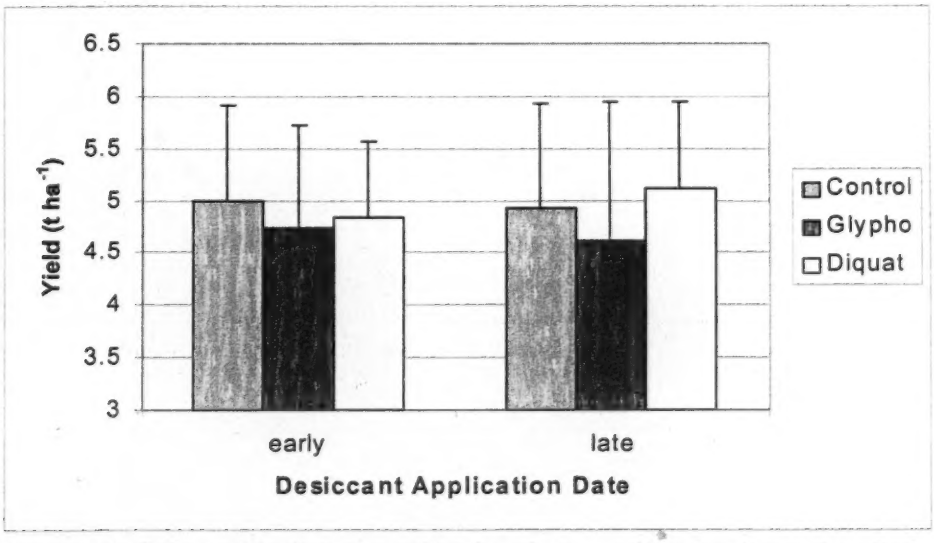

Figure 4.4: Effect of desiccant application date on yield for three chemical desiccant treatments grown at Neerlandia in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.05).

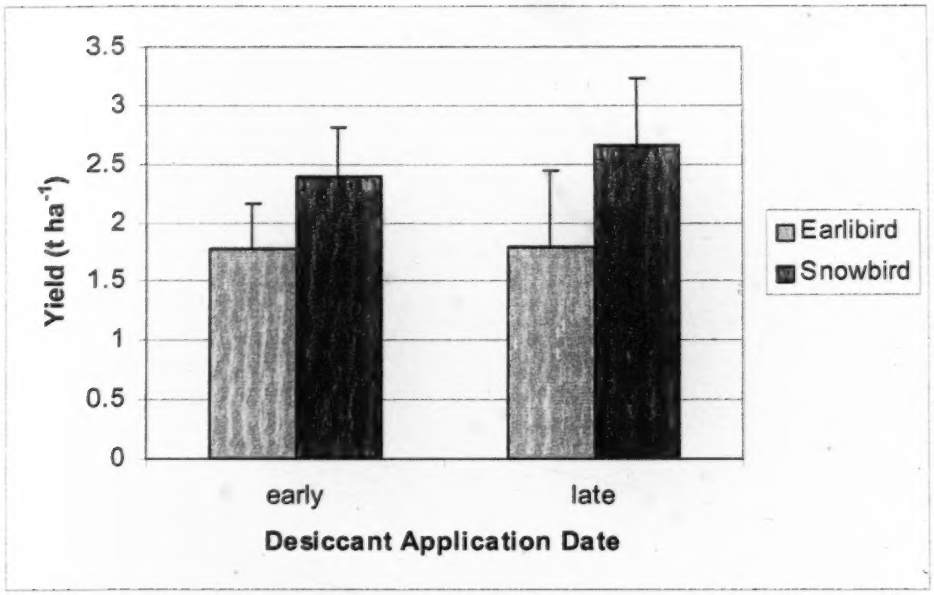

Figure 4.5: Effect of desiccant application date on yield for two faba bean cultivars grown at Legal in 2001. Bars represent the standard deviation of the mean. (Desiccant application date x cultivar interaction; P≤0.05).

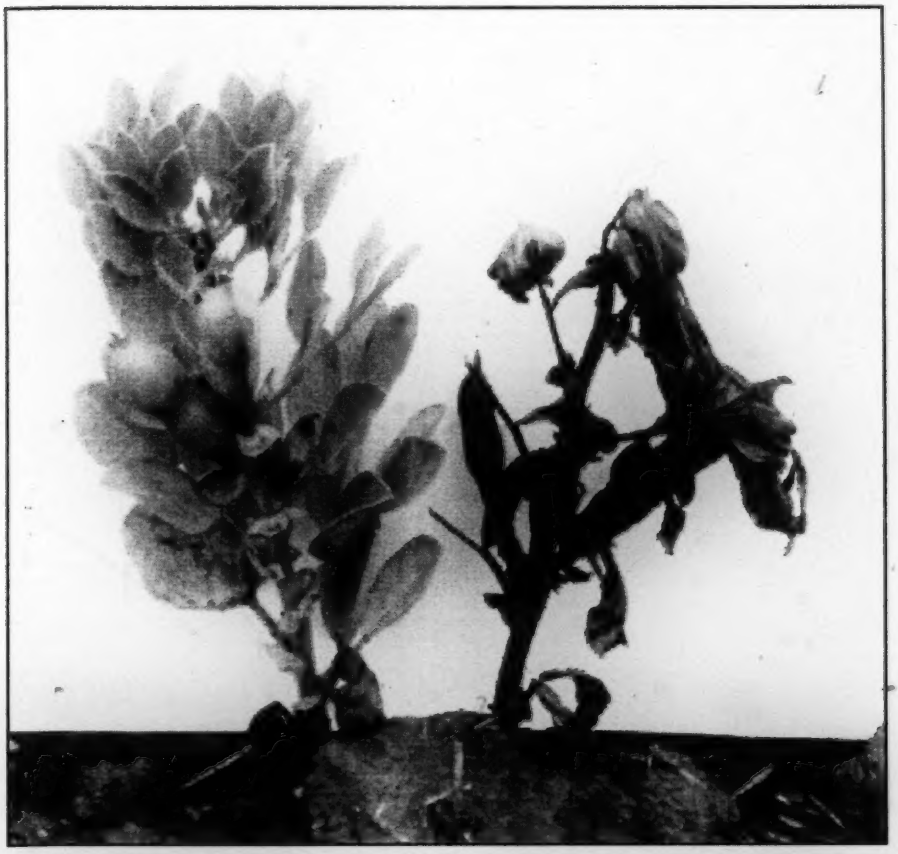

Plate 4-1: Earlibird faba bean plants on August 6, 2002 at Legal. Left, healthy plant. Right, plant is infected with *Fusarium* sp. and *Verticillium* sp. which are causing common vascular wilt. Between 10 to 15% of the Earlibird sub-sub plots suffered from the fungal infection at Legal in 2002.

Plate 4-2: Faba bean plants on September 5, 2002 at Neerlandia, five days after the early desiccant application date and one day after the late desiccant application date. Left, plants were desiccated with diquat five days ago. Right, plants were desiccated with diquat the previous evening. Diquat will begin to yellow a plant within a few hours of application and desiccation of the plant will occur rapidly until death (Ali et al., 2001).

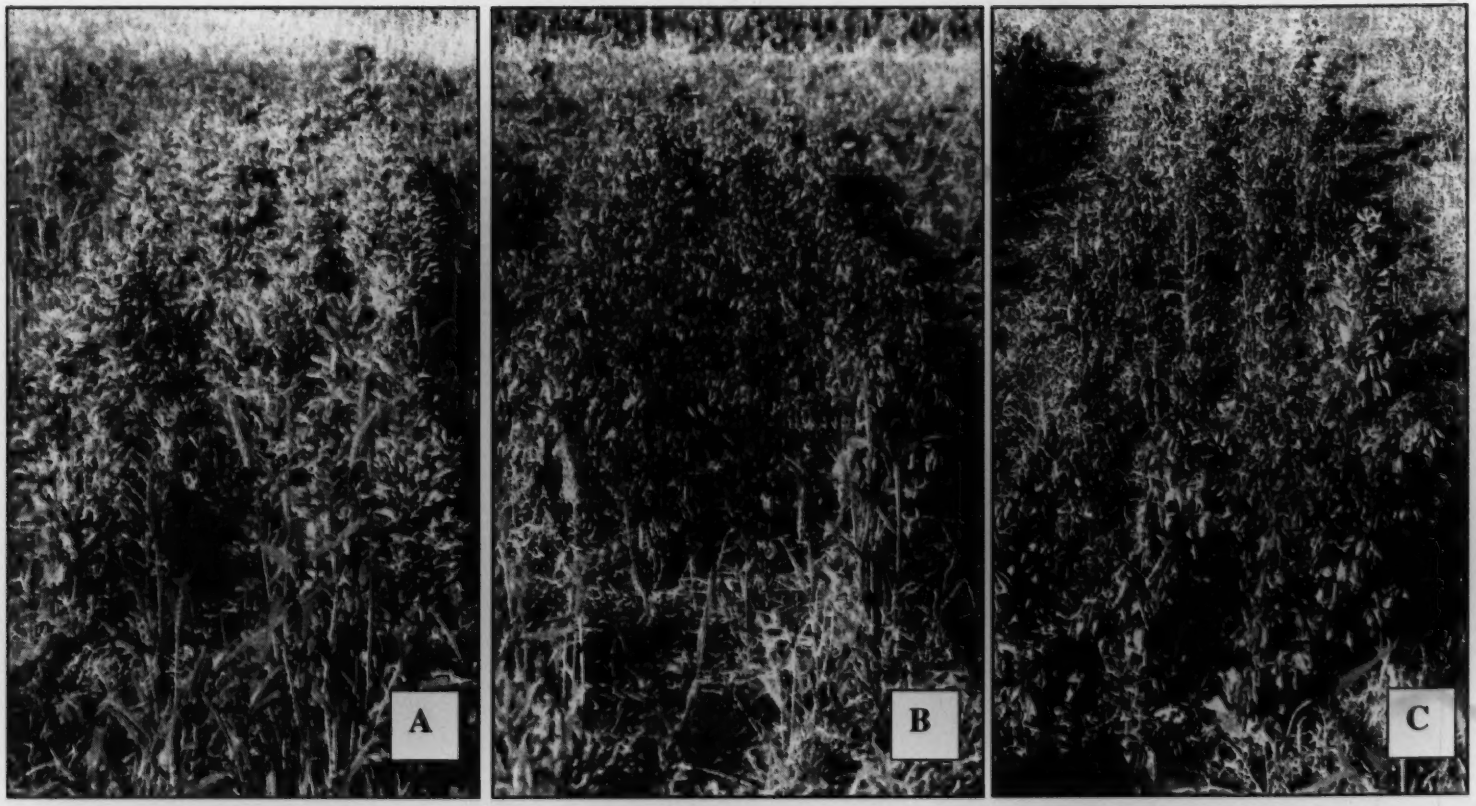

Plate 4-3: Faba bean plots on September 17, 2002 at Neerlandia, 13 days after late desiccation application date. A. untreated control, B. Diquat desiccant application, and C. Roundup desiccant application.

4.5 Literature Cited

Alberta Agriculture Weather Summary, 2001 and 2002. Electronic reference. Retrieved September 17, 2002. from http://www.agric.gov.ab.ca/climate

Anonymous. 2002. 'Earlibird' variety description. Plant Breeders' Rights Office. Plant Varieties Journal. 42:58.

Anonymous. 2003. 'Snowbird' variety description. Plant Breeders' Rights Office. Plant Varieties Journal. 46:57.

Ali, S., Calpas, J. and Bourne, J.B., eds., 2001. Crop Protection. Alberta Agriculture, Food and Rural Development Information Package Centre. Edmonton, Alberta, pp. 357-358.

Betts, M.F. and I.N. Morrison. 1980. Effects of chemical desiccation versus swathing on seed yield and quality of faba beans (*Vicia faba*). Can. J. Plant Sci. 60:1115-1121.

Bowser, W.E., A.A. Kjearsgaard, T.W. Peters, and R.E. Wells. 1962. Soil Survey of Edmonton Sheet (83-H). University of Alberta.

Corbett, J.R., K. Wright, and A.C. Baillie. 1984. The biochemical mode of action of pesticides, 2nd ed. Academic press, London and New York.

Environment Canada. Canadian Climate Normals 1971-2000. Electronic reference. Retrieved January 28, 2003. from http://www.msc-smc.ec.gc.ca/climate/climate_normals/index_e.cfm

Farmzone Historical Accumulated Totals, 2001. Electronic references. Retrieved June 20, 2002, from http://www.farmzone.com

Grzesiuk, S. and E. Sojka. 1961. Studies on the physiology or maturing small field bean seeds (*Vicia faba* L. ssp. Minor) Rocz. Nauk. Rolniczych, Ser. A. Roslinna 83:735-770. (Biological abstracts 36:20552).

Hebblethwaite, P.D. 1970. Production, marketing and utilization of the field bean. MSc thesis, University College of North Wales. *In* P.D. Hebblethwaite, ed. The Faba Bean (*Vicia faba* L.). Butterworths, London.

Knott, C.M., A.J. Biddle and B.M. McKneown. 1994. PGRO Field Bean Handbook. Processors and Growers Research Organization, Peterborough, UK.

Nash, M.J. 1978. Crop conservation and storage in cool temperate climates. Pergamon Press, Oxford.

Norwest Labs. 2002. Soil Test Recommendations for Faba Beans. Edmonton, AB.

Rowland, G.G. 1978. Effects of planting and swathing dates on yield, quality and other characteristics of faba beans (*Vicia faba*) in central Saskatchewan. Can. J. Plant Sci. 58:1-6.

SAS Institute. 1999. Version 8.1 ed. SAS Institute, Cary, N.C.

Summers, L.A. 1980. The bipyridinium herbicides. Academic Press. London, 1980.

Thompson, R. and H. Taylor. 1982. Prospects for *Vicia faba* L. in North Europe. Outlook on Agriculture. Volume II, No. 3. 127-133.

Wynnyk, A., J.D. Lindsay, and Wm. Odynsky. 1696. Soil Survey of the Whitecourt and Barrhead Area. University of Alberta.

Chapter 5
Tannin-free Faba Bean Production in North Central Alberta

5.1 General Discussion and Conclusions

Traditional tannin-containing faba beans have been grown around the world for thousands of years, and can be successfully grown in north central Alberta. In the last two and a half decades, the development of tannin-free faba bean cultivars has created the potential for a new crop that could be grown in this area. Tannin-free faba beans are superior to tannin-containing faba beans as a protein source for monogastric animals as they do not contain antinutritional factors. North central Alberta production of tannin-free faba beans could serve the protein feed supplement markets and possibly human consumption markets.

It was hypothesized that in order for tannin-free faba beans to be grown in north central Alberta, a modified production system would be required. Traditional tannin-containing faba beans are seeded early, prior to May 7th, at a seeding rate of 40 plants m^{-2} (Park and Lopetinsky, 1999). The absence of tannin in the seed coat of tannin-free faba beans has previously been associated with an increased incidence of seedling disease and emergence problems (Kantar et al., 1996). It was thus assumed that a higher seeding rate, and delayed seeding date, would be necessary to achieve adequate plant populations and maximum yield for the tannin-free cultivars. In this study, the effects of cultivar, seeding date, and seeding rate on faba bean yield, quality, and yield components were investigated, along with the

effects of chemical desiccation on faba bean yield and quality. By integrating the results of this study a foundation of knowledge, specific to north central Alberta faba bean production, has been obtained which can be used to provide information to producers and direct future studies.

In order for tannin-free faba bean cultivars to be accepted by producers, the new cultivars must have similar, if not better, yield and quality as compared to the traditional, tannin-containing cultivars. In this study, the tannin-free cultivar, Snowbird, proved to be one of the best yielding cultivars in three site years. Lower yields were observed only at Legal in 2002, where extreme drought conditions occurred. This yield reduction did not appear to be connected to the seed tannin content, but rather to the harsh growing conditions. In terms of quality, on average, the tannin-free cultivars had a higher crude protein content (27%) compared to the tannin-containing cultivars (26%). The tannin-free cultivar, Cresta, had a crude protein content of 29%, which is superior to the average crude protein content of field peas (17%) (Park and Lopetinsky, 1999), which are currently being used as a locally produced protein supplement. The high yield and quality of the tannin-free cultivars demonstrates their suitability for production in north central Alberta.

Under average, north central Alberta growing conditions (such as those observed in 2001), tannin-free faba beans can be grown at low seeding rates, of 32 plants m^{-2}, and they will achieve high yields with reduced seeding costs. In terms of an optimum seeding date, the mid seeding date (May 4th in 2001 and May 17th in 2002) produced superior yields. In the second year of the study (2002), below

average rainfall and above average temperatures in June and July were not typical of growing conditions in north central Alberta. Based on these unusual environmental conditions, it would be useful to have another year of data, from average growing conditions, to support our findings.

In the spring of 2002, when soil conditions were wet and cool, tannin-free cultivars failed to reach target populations. It was presumed that the tannin-free cultivars suffered from pathogen infection although testing for pathogen infection was beyond the scope of this project. Future studies need to be conducted on cool, wet seed beds to determine if pathogen infection is reducing plant populations of tannin-free cultivars, and if these problems can be remedied with seed fungicide treatments. An alternative to fungicide use would be to investigate the possibility of minimizing fungal growth in the soil by examining residue management.

The reduced plant populations observed for the tannin-free cultivars did not translate into reduced yields for Snowbird at Neerlandia in 2002. This along with successful yields achieved from the low plant populations in 2001, is further evidence that higher plant populations may not be necessary for tannin-free cultivars to achieve optimum yields.

Yield components were examined to determine how tannin-free and tannin-containing cultivars build yield. In our study, there were no obvious differences between the strategies used by tannin or tannin-free cultivars to build yield. According to the yield component study, increased yields can largely be attributed to increases in plant populations. However, correlations of yield components with

yield showed very few significant results. This inconsistency may be explained by the fact that individual yield components were measured on a per plant basis, while yield and seed weight were measured on a per plot basis. To obtain a more accurate view of how yield components contribute to overall yield, under north central Alberta growing conditions, both yield and yield components need to be measured on a per plant basis. Husain et al. (1988) reported that differences between plot yield and yield based on the sum of yield components were often substantial. A greater understanding of how individual yield components contribute to yield would provide plant breeders with more precise selection criteria for increasing yield in new cultivars.

A second requirement for the acceptance of tannin-free faba beans in north central Alberta is that cultivars must be able to grow and mature within the short growing season. Many of the older traditional faba bean cultivars grown in Alberta were indeterminate and required a long growing season. The two most commonly grown cultivars in the area, Earlibird and Snowbird, are relatively determinate and early maturing (Anonymous, 2002; Anonymous, 2003). At the time of harvest, undesiccated Earlibird plots contained 35% black stems (average of four site years) and undesiccated Snowbird plots contained 33% black stems (average of four site years). However, harvesting is typically done when 90% of the stems are black (Knott et al., 1994). The low percentage of black stems, at the time of harvest, indicates that both traditional and tannin-free cultivars would benefit from chemical

desiccation and there is no maturity advantage of the traditional cultivars over the tannin-free cultivars.

In order to advance maturity, we found that Earlibird and Snowbird can be desiccated with diquat, as early as the 60 – 70% black pod stage, and this was the most effective means of hastening plant maturity without sacrificing yield or seed weight. Desiccation prior to the 60-70% black pod stage may be possible, however, earlier desiccation has been shown to cause seed weight and yield decreases with late maturing, indeterminate faba bean cultivars (Betts and Morrison, 1980). This is an area which requires further investigation.

There is potential for large increases in tannin-free faba bean acres to occur, in north central Alberta. We have demonstrated that the potential agronomic complications associated with tannin-free faba bean production are minor and can be easily overcome. The next step is the development of markets for tannin-free faba beans.

"We can grow them! Now we just have to sell them!"

5.2 Literature Cited

Anonymous. 2002. 'Earlibird' variety description. Plant Breeders' Rights Office. Plant Varieties Journal. 42:58.

Anonymous. 2003. 'Snowbird' variety description. Plant Breeders' Rights Office. Plant Varieties Journal. 46:57.

Betts, M.F. and I.N. Morrison. 1980. Effects of chemical desiccation versus swathing on seed yield and quality of faba beans (*Vicia faba*). Can. J. Plant Sci. 60:1115-1121.

Husain, M.M., G.D. Hill and J.N. Gallagher. 1988. The response of field beans (*Vicia faba* L.) to irrigation and sowing date 1.Yield and yield components. J. Agric. Sci. Camb. 111:221-232.

Kantar, F., P.D. Hebblethwaite and C.J. Pilbeam. 1996. Factors influencing disease resistance in high and low tannin *Vicia faba*. J. Agric. Sci., Camb. 127: 83-88.

Knott, C.M., A.J. Biddle and B.M. McKneown. 1994. PGRO Field Bean Handbook. Processors and Growers Research Organization, Peterborough, UK.

Park, B. and K. Lopetinsky. 1999. Pulse Crops in Alberta. Alberta Agriculture, Food and Rural Development, Edmonton, AB. pp.123-140.

Appendix I
Qualitative Description of Growing Conditions

Legal 2001 – best Legal site (but worse than either Neerlandia site). Growth on average looked fairly good. Soil was dry and warm at time of planting. However late season (end of July) waterlogging occurred which seemed to result in premature leaf drop.

Neerlandia 2001 – very good site. Soil at seeding was warm and dry. Lush growth, tall plants, lots of biomass, and very good yields. This site had maximum rainfall.

Legal 2002 – worst site, growth was very poor due to extreme drought. At seeding soil was cold and wet, following that there was very little moisture. Plants were short, there was little biomass. Some Earlibird plants became infected with *Fusarium* and *Verticillium* causing stems to blacken prematurely. Incredibly small plants poor yields.

Neerlandia 2002 – excellent site. Soil at seeding was extremely cold and wet. Plant growth was lush, plants were tall with lots of biomass. Best yields. Rainfall was fairly evenly distributed.

Table I-1 Seeding rates (kg ha^{-1}) of cultivars seeded in 2001 and 2002*

Cultivar	32 plants m^{-2}		43 plant m^{-2}		65 plants m^{-2}	
	2001	2002	2001	2002	2001	2002
Earlibird	230	211	306	282	459	422
CDC Blitz	150	123	200	164	301	246
Snowbird	208	192	277	256	416	384
Cresta	169	160	226	214	339	320

* In Chapter 4, only the cultivars Earlibird and Snowbird were used and they were seeded at 43 plants m^{-2}.

Table I-2 Germination, vigor, emergence testing and electrical conductivity (EC) (dSm^{-1}) of faba bean cultivars seeded in 2001 and 2002*

Cultivar	Germination (%)	Vigor (%)	Emergence (%)	EC (dSm^{-1})
2001				
Earlibird	81	82	86	16
CDC Blitz	77	85	85	15
Snowbird	74	83	86	19
Cresta	81	79	85	14
2002				
Earlibird	99	92	95	n/a
CDC Blitz	91	82	87	n/a
Snowbird	96	97	98	n/a
Cresta	97	91	94	n/a

* In Chapter 4, only the cultivars Earlibird and Snowbird were used.

Table I-3 Soil Analysis for Legal and Neerlandia 2001 (estimate of soil nutrients at beginning of the growing season)

Location	Depth (cm)	Nutrient Content (kg ha^{-1})								Soil Quality	
		Nitrate - N		Phosphorous		Potassium		Sulphate – S			
		test	reco	test	reco	test	reco	test	reco	pH	EC
Legal	0-15	52	0	60	39	388	0	38	0	6.5	0.41
	15-30	29		13		237		45		6.7	0.49
Neer	0-15	85	0	134	0	753	0	38	0	5.8	0.49
	15-30	56		60		316		34		6.6	0.47

Test = soil nutrient content from soil test analysis, Reco = soil test nutrient recommendations for faba bean production, EC = electrical conductivity (dSm^{-1}).

Table I-4 Soil Analysis for Legal and Neerlandia 2002

Location	Depth (cm)	Nutrient Content (kg ha^{-1})											Soil Quality	
		Nitrate - N			Phosphorous			Potassium			Sulphate – S				
		test	reco	appl	test	reco	appl	test	reco	appl	test	reco	appl	pH	EC
Legal	0-15	28	0	7	55	37	32	278	47	0	10	14	0	6.3	0.31
	15-30	22			16			155			7			5.3	0.25
Neer	0-15	8	0	7	125	24	32	674	0	0	40	0	0	7.0	0.60
	15-30	15			>134			623			>45			7.3	0.80

Test = soil nutrient content from soil test analysis, Reco = soil test nutrient recommendations for faba bean production, Appl = soil nutrients added as fertilizer, EC = electrical conductivity (dSm^{-1}).

Table I-5 Pre-Seeding and Post-Harvest Soil Analysis Comparison for Legal and Neerlandia 2002

Location	Depth (cm)	Nutrient Content (kg ha^{-1})		Soil Quality			
		Nitrate - N		pH		EC	
		pre	post	pre	post	pre	post
Legal	0-15	28	73	6.3	5.7	0.31	0.45
	15-30	22	69	5.3	5.9	0.25	0.45
Neer	0-15	8	9	7.0	6.5	0.60	0.33
	15-30	15	4	7.3	7.0	0.80	0.37

Pre = pre-seeding soil nutrient content from soil test analysis, Post = post-harvest soil nutrient content from soil test analysis, EC = electrical conductivity (dSm^{-1}).

Table I-6 Soil temperatures at time of seeding for Legal and Neerlandia in 2001 and 2002 taken at 15cm depth*

Seeding Date	Soil Temperature °C			
	Legal		Neerlandia	
	2001	2002	2001	2002
Early [1]	13.3	7.0	11.5	- 4.0
Mid [2]	15.2	8.0	12.0	2.0
Late [3]	15.2	11.0	12.8	7.0

[1] Early seeding date was April 25th in 2001 and May 8th in 2002
[2] Mid seeding date was May 4th in 2001 and May 17th in 2002
[3] Late seeding date was May 14th in 2001 and May 27th in 2002

* In Chapter 4, the entire experiment was seeded at the early seeding date.

Table I-7 Summary of monthly precipitation averages (mm) for Legal and Neerlandia for May to September in 2001 and 2002.

Month	Legal 2001 Site Ppt'e	Legal 2002 Site Ppt'e	30 year average for Legal Area[1]	Neer 2001 Site Ppt'e	Neer 2002 Site Ppt'e	30 year average for Neer Area[2]
May	32	0	45	13	4	56
June	37	5	89	58	29	98
July	189	38	96	156	111	102
August	83	40	75	25	36	73
September	2	8	40	20	13	46
Total	341	91	345	272	193	375

[1] 30 Year Average Precipitation Data for Namao, AB (Latitude 53° 40'N Longitude 113° 28' W; Elevation 687.9m) from Environment Canada. To be compared to the precipitation data for the Legal site in 2001 and 2002.
[2] 30 Year Average Precipitation Data for the AAFRD North Western Agriculture Region (Alberta Agriculture Weather Summary, 2002). To be compared to the precipitation data for the Neerlandia site in 2001 and 2002.

Table I-8 Mean Monthly Temperatures and Growing Degree Days in the AAFRD North Western Agriculture Region for 2001, 2002 and 30 Year Average (Alberta Agriculture Weather Summary, 2002).

Month	Mean Temperature °C			Growing Degree Days (Above 5 °C)		
	2001	2002	30 Year Avg.	2001	2002	30 Year Avg.
May	11.2	7.9	10.3	188	121	181
June	13.2	14.7	14.1	245	292	291
July	16.2	17.0	16.2	349	372	348
August	16.7	14.6	15.3	371	299	319
September	11.4	9.5	10.2	192	143	165

Table I-9 Calculated growing degree days (GDD) for each seeding date from the time of seeding until the time of harvest in 2001 and 2002. *

Seeding Date	Legal GDD		Neerlandia GDD	
	2001[1]	2002[1]	2001[2]	2002[3]
Early	1352	1530	1056	1159
Mid	1298	1496	1025	1131
Late	1244	1457	987	1083

[1] GDD calculations based on daily temperature data from the Edmonton Research Station (ERS) meteorological station.

[2] GDD for the Farmzone Barrhead/Whitecourt/Swan Hills Region (Farmzone Historical Accumulated Totals, 2001)

[3] GDD calculations based on daily temperature data from the Dapp, AB Drought Monitoring Station.

* In Chapter 4, the entire experiment was seeded at the early seeding date.

Table I-10 Time of plant population counts in 2001 and 2002 *

Seeding Date	Time of Plant Population Count (Days after Seeding)						
	2001		2002				
	1st count	2nd count	1st count	2nd count	3rd count	4th count Legal	5th count Neer
Early	19	23	23	27	31	124	143
Mid	18	21	18	22	26	115	134
Late	17	22	16	20	24	105	124

* In Chapter 4, the entire experiment was seeded at the early seeding date.

Table I-11 Nine-point chocolate spot assessment scale used in 2001 and 2002

Rating	Disease symptoms and signs
1	No symptoms, leaves healthy and green
2	Non-aggressive lesions on lower leaves
3	Leaves display small brown dots (PlateI-1)
4	Spots enlarge and form rounded sunken spots
5	Infected areas have tan centers and reddish brown margins (Plate I-1)
6	Lesions are entirely reddish brown (Plate I-1)
7	Lesions are large brown blackish blotches (Plate I-1)
8	Lesions merge - blackening and partial defoliation
9	Dead or excessive defoliation

Table I-12 Leaf Drop Rating Guidelines used in 2001

Defoliation Rating	Description
No Leaf Drop = 0	90 – 100% of the leaves remain on the plant
Slight Leaf Drop = 1	60 – 90 % of the leaves remain on the plant
Moderate Leaf Drop = 2	30 – 60 % of the leaves remain on the plant
Severe Leaf Drop = 3	0 – 30 % of the leaves remain on the plant

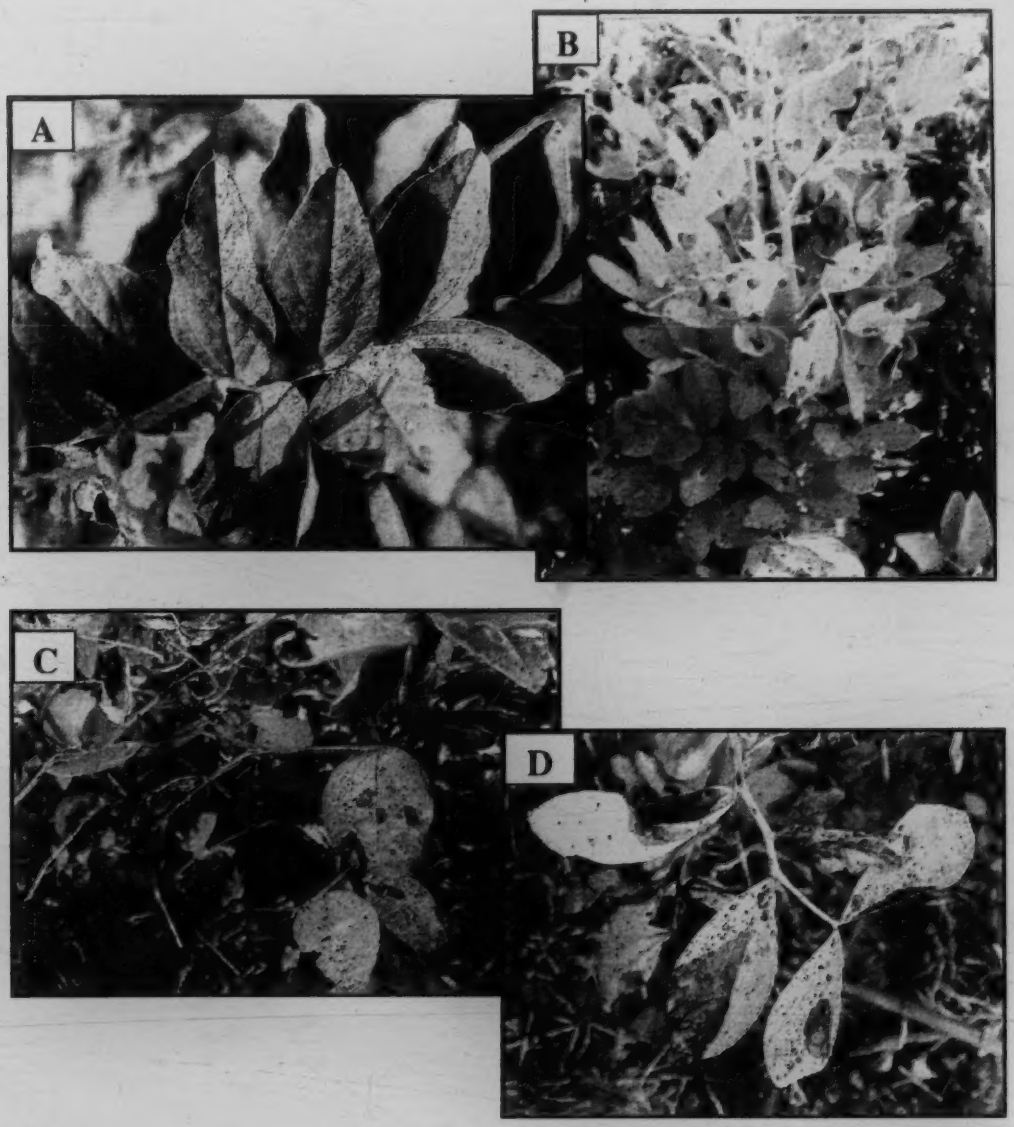

Plate I - 1: Chocolate Spot (A) Leaves display small brown dots, rating 3; (B) Infected areas have tan centers and reddish brown margins, rating 5; (C) Lesions are entirely reddish brown, rating 6; (D) Lesions are large brown blackish blotches, rating 7.

Appendix II

Sample Analysis of Variance used in Chapter 2 and 3

Table II-1 Analysis of Variance for yield of faba beans grown at Neerlandia and Legal in 2001 and 2002.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	251	1949348365	7766328	52.92	<.0001
Error	324	47553251	146769		
Corrected Total	575	1996901616			

R-Square	Coefficient of Variation	Root MSE	Total Mean
0.976186	10.80861	383.1048	3544.441

Tests of Hypotheses Using the Type III MS for block(year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Year	1	714870	714870	0.35	0.5675
Location	1	1520792007	1520792007	735.36	<.0001
Year *Location	1	118942654	118942654	57.51	<.0001

Tests of Hypotheses Using the Type III MS for block*date(year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Date	2	7806241.80	3903120.90	3.73	0.0390
Date*year	2	9135911.66	4567955.83	4.36	0.0242
Date*location	2	856473.59	428236.79	0.41	0.6689
Date*year*locat	2	11478732.30	5739366.15	5.48	0.0110

Tests of Hypotheses Using the Type III MS for block*rate(date*year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Rate	2	14224584.61	7112292.30	15.47	<.0001
Rate*year	2	1477716.41	738858.20	1.61	0.2077
Rate*year*locat	2	1896657.96	948328.98	2.06	0.1346
Date*rate	4	3396922.31	849230.58	1.85	0.1293
Date*rate*year	4	773473.78	193368.45	0.42	0.7934
Date*rate*locat	4	171492.73	42873.18	0.09	0.9843
Dat*rat*yr*locat	4	2234844.85	558711.21	1.21	0.3120

Tests of Hypotheses Using the Type III MS for block*cultivar(date*rate*year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Cv	3	46928986	15642995	106.58	<.0001
Cv*year	3	12204200	4068067	27.72	<.0001
Cv*location	3	20933966	6977989	47.54	<.0001
Cv*year*location	3	5788285	1929428	13.15	<.0001
Cv*date	6	39811140	6635190	45.21	<.0001
Cv*date*year	6	11086664	1847777	12.59	<.0001
Cv*date*location	6	13655694	2275949	15.51	<.0001
Cv*date*year*locat	6	7187671	1197945	8.16	<.0001
Cv*rate	6	1395523	232587	1.58	0.1508
Cv*rate*year	6	529381	88230	0.60	0.7294
Cv*rate*location	6	1747301	291217	1.98	0.0675
Cv*rate*year*locat	6	1046434	174406	1.19	0.3121
Cv*date*rate	12	3114902	259575	1.77	0.0523
Cv*date*rate*year	12	1022154	85180	0.58	0.8579
Cv*date*rate*locat	12	1784008	148667	1.01	0.4364
Cv*dat*rat*yr*locat	12	2473300	206108	1.40	0.1621

Table II-2 Analysis of Variance for yield of faba beans grown at Legal in 2001.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	62	67743036.85	1092629.63	7.90	<.0001
Error	81	11201412.31	138289.04		
Corrected Total	143	78944449.16			

R-Square	Coefficient of Variation	Root MSE	Total Mean
0.858110	15.43550	371.8723	2409.201

Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Block	3	4658459	1552820	11.23	<.0001
Date	2	371756.4	185878.2	1.34	
Block*date	6	13659353	2276559	16.46	<.0001
Rate	2	1958155	979077.3	7.08	
Date*rate	4	3156807	789201.9	5.71	
Block*rate(date)	18	14450504	802805.8	5.81	<.0001

Tests of Hypotheses Using the Type III MS for block*date as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Date	2	371756.4	185878.2	0.08	0.9226

Tests of Hypotheses Using the Type III MS for block*rate(date) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Rate	2	1958155	979077.3	1.22	0.3186
Date*rate	4	3156807	789201.9	0.98	0.4415

Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
Cv	3	25529220	8509740	61.54	<.0001
Cv*date	6	1407341	234556.8	1.7	0.1325
Cv*rate	6	904680.9	150780.1	1.09	0.3753
Cv*date*rate	12	1646762	137230.2	0.99	0.4636

Appendix III

Sample Analysis of Variance used in Chapter 4

Table III-1 Analysis of Variance for yield of faba beans in desiccation experiment grown at Neerlandia and Legal in 2001 and 2002.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	119	735047819.7	6176872.4	50.55	<.0001
Error	72	8798265.7	122198.1		
Corrected Total	191	743846085.5			

R-Square	Coefficient of Variation	Root MSE	Total Mean
0.988172	11.10957	349.5685	3146.552

Tests of Hypotheses Using the Type III MS for block(year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
year	1	25804534.1	25804534.1	18.33	0.0011
location	1	561399840.3	561399840.3	398.86	<.0001
year*location	1	24144288.5	24144288.5	17.15	0.0014

Tests of Hypotheses Using the Type III MS for block*chemical(year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
chemical	2	1449269.042	724634.521	1.75	0.1956
chemical*year	2	32205.167	166102.583	0.40	0.6743
chemical*location	2	73671.542	86835.771	0.21	0.8125
chem.*year*location	2	74279.292	337139.646	0.81	0.4553

Tests of Hypotheses Using the Type III MS for block*date(chemical*year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
date	1	494508.000	494508.000	2.81	0.1022
date*year	1	18135.187	18135.187	0.10	0.7500
date*location	1	8138.021	8138.021	0.05	0.8309
date*year*location	1	61204.083	61204.083	0.35	0.5589
chemical*date	2	1186867.125	593433.562	3.37	0.0454
chemical*date*year	2	420576.500	210288.250	1.2	0.3142
chemica*date*locatio	2	77579.542	38789.771	0.22	0.8031
chem.*date*yr*locat	2	203033.292	101516.646	0.58	0.5665

Tests of Hypotheses Using the Type III MS for block*cultivar(chemical*date*year*location) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
cv	1	59900242.5	59900242.5	490.19	<0.0001
cv*year	1	18.8	18.8	0	0.9902
cv*location	1	20186508.0	20186508.0	165.19	<.0001
cv*year*location	1	3717976.7	3717976.7	30.43	<.0001
cv*chemical	2	571113.2	285556.6	2.34	0.1039
cv*chemical*year	2	189330.9	94665.4	0.77	0.4647
cv*chemical*location	2	94443.9	47221.9	0.39	0.6809
cv*chemi*year*locati	2	4777.6	2388.8	0.02	0.9806
cv*date	1	455130.7	455130.7	3.72	0.0576
cv*date*year	1	183150.5	183150.5	1.5	0.2248
cv*date*location	1	10354.7	10354.7	0.08	0.7718
cv*date*year*locatio	1	14840.3	14840.3	0.12	0.7285
cv*chemical*date	2	5064.5	2532.2	0.02	0.9795
cv*chem*date*year	2	52234.5	26117.3	0.21	0.8081
cv*chem*date*locati	2	10901.4	5450.7	0.04	0.9564
cv*chem*dat*yr*loca	2	31342.0	15671.0	0.13	0.8798

Table III-2 Analysis of Variance for yield of faba beans in desiccation experiment grown at Legal in 2001.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	29	17534443	604636	8.04	<.0001
Error	18	1354194	75232.99		
Corrected Total	47	18888637			

R-Square	Coefficient of Variation	Root MSE	Total Mean
0.928306	12.71131	274.2863	2157.813

Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
block	3	2709043.6	903014.5	12	0.0001
chemical	2	803421.13	401710.6	5.34	
block*chemical	6	3166202.4	527700.4	7.01	0.0006
date	1	205277.52	205277.5	2.73	
chemical*date	2	1254655.3	627327.6	8.34	
block*date(chem)	9	2318577.9	257619.8	3.42	0.0126

Tests of Hypotheses Using the Type III MS for block*chemical as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
chemical	2	803421.13	401710.6	0.76	0.5074

Tests of Hypotheses Using the Type III MS for block*date (chemical) as an Error Term					
Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
date	1	205277.52	205277.5	0.8	0.3953
chemical*date	2	1254655.3	627327.6	2.44	0.1428

Source	Degrees of Freedom	Type III SS	Mean Square	F Value	Pr > F
cv	1	6705822.5	6705823	89.13	<.0001
cv*chemical	2	166674.54	83337.27	1.11	0.3518
cv*date	1	193167.19	193167.2	2.57	0.1265
cv*chemical*date	2	11601.375	5800.687	0.08	0.9261